

Report No 88

Hydrogen Fuel-Cell buses: examination of issues to implement a zero-emission future with hydrogen-fueled buses and agenda for action

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Environment Pollution (Prevention and Control) Authority for NCR (EPCA)

The Hon'ble Supreme Court in its order dated 2.7.2018 directed EPCA to look into the issue of hydrogen fuel cell buses. EPCA is filing this report in compliance with this direction. EPCA has held consultations with experts in the country, particularly, the scientists from the Indian Oil Corporation Limited (IOCL), R&D Centre which has worked extensively on hydrogen cell fuel buses. It has also consulted with government officials from key ministries as well as representatives of Tata Motors, which has deployed the first hydrogen fuel cell bus in the country and Indraprastha Gas Limited (IGL).

1. Hydrogen fuel-cell buses: Global experience

Hydrogen fuelled, fuel-cell vehicles are seen to be the most promising low-emission option. In this case, hydrogen and oxygen is used to produce electricity, which runs a motor. Fuel cell vehicles are considered to be a type of electric vehicles (EVs) because they also use electricity to run, which is generated in-situ using hydrogen. The advantage of hydrogen fuel cell vehicles over EV vehicles is that their range and re-fuelling process is similar with conventional vehicles.

The fuel is hydrogen, which produces only water and heat as a by-product and so these vehicles do not have any tailpipe emissions when driven, like EVs. The size of the battery is however much smaller in fuel-cell hydrogen vehicles as compared to EVs and this superior energy-density is what is driving the interest in hydrogen. But battery technology is also progressing fast and therefore, there is a clear competition between these two clean energy sources.

The question is if the production of the fuel creates pollution. In the case of EVs, the source of electricity is where the pollution is generated. It is found that if electricity is generated using coal power plants, then emissions are roughly equivalent – from the conventional fuelled (petrol or diesel) but best-in-class low emission vehicle as compared to EVs. The only difference is where

the pollution is generated. In the case of EVs, emissions are not from the tail-pipe of each vehicle but from the stack of the thermal power plant.

This is why electric vehicles are seen to be better where there is local pollution – as in the case of Delhi, as compared to conventional fuel vehicles. This is also why the effort in the case of use of electric vehicles is to improve the emissions from electricity generation by moving to cleaner natural gas or renewable sources like solar or wind.

Producing hydrogen fuel also leads to pollution. The question also is what is the source of hydrogen? In most cases, hydrogen is produced from natural gas, which is a fossil fuel. The other option, which is expensive and has high energy costs, is to produce hydrogen from water. The question is if the life-cycle of hydrogen vehicles – fuel and battery – is lower or higher than battery vehicles – fuel and battery.

A review of global literature points to the advantage that hydrogen-fuel cell vehicles have as against battery vehicles when the full life-cycle cost is estimated.¹ But the debate is far from over and these two new-age technologies are competing for advantage.

Both EVs and Hydrogen-fuel cell vehicles will require separate infrastructure for fuelling. Currently, the cost of setting up infrastructure for EV's is cheaper and simpler – network of charging stations will be required specific to the vehicles that are to be operated. The cost of setting up hydrogen-fuel supply and dispensing systems is still not scaled up enough in the world to understand its full economics.

But countries are beginning to invest in this infrastructure. Japan, for instance, has stated that the 2020 Olympics will be hydrogen-fuelled –thousands of fuel-cell vehicles are expected to hit the road by then (100 of these will be buses). The country has decided that hydrogen is the fuel of the future and is investing in building the infrastructure, whatever the complexity and costs – it had some 80 fuelling stations in 2017 and plans to increase these to 160 by 2020 and 900 by 2030.²

California in the US has some 31 hydrogen fuelling stations, but there are concerns if the costs are sustainable – the current stations remain heavily

¹<https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/hydrogen-the-next-wave-for-electric-vehicles>

²<https://www.ft.com/content/98080634-a1d6-11e7-8d56-98a09be71849>

subsidised³. California has an ambitious clean vehicle plan, which includes investment in electric and hydrogen vehicles. According to reports, the state will spend more than \$2.5 billion in clean energy funds to accelerate sales of hydrogen and battery vehicles. That includes \$900 million earmarked to complete 200 hydrogen stations and 250,000 EV charging stations by 2025. There is some criticism if the state should invest only in e-vehicles and not in creating a separate hydrogen infrastructure.

South Korea in Asia and Germany in Europe have also decided to invest in hydrogen fuel cell vehicles. South Korea will invest some \$2.3 billion and has set a target of 100 fuelling stations by 2020 and 310 by 2022. Germany has 56 stations and plans to double these by 2019. In both cases, abundant and cheap wind energy will be used to produce hydrogen from electrolysis.

As the cost of infrastructure for supply is high, countries are also carefully devising plans so that they prioritise use and concentration of fuelling stations. For instance, Germany's H2Mobility plan estimates that it will get nationwide coverage for hydrogen by building only 400 stations. Globally some 2,800 fuelling stations are planned by 2025, which is tiny as compared to the over 6,00,000 petrol and diesel fuelling stations⁴. But the aim is to target key vehicle segments and therefore, maximise the benefits.

The highest priority segments are buses, trucks and even trains – China and Germany have such trains in operation.

Currently there are some 330 hydrogen-fuelled buses on the road across the world (Europe 292, California 26, China 15). But both China and South Korea have ambitious and aggressive plans to ramp up production of fuel-cell hydrogen buses.

2. India's hydrogen-fuel cell vehicle programme

In March 2018, Tata Motors, in collaboration with IOCL R&D has brought on road 2 hydrogen fuel cell buses. These are expected to go on the road – between Delhi and Faridabad – shortly. The permission for running the bus is required from the Ministry of Road Transport and Highways (MoRTH), which after meeting with EPCA has been given as of Friday, July 13, 2018 – but only

³<https://www.bloomberg.com/news/articles/2018-03-05/california-should-focus-on-electric-cars-not-hydrogen-fuel>

⁴<https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/hydrogen-the-next-wave-for-electric-vehicles>

to ply in Haryana. The bus has a range per fill of 400-500 km, which makes it much better than a comparative E-bus.

The Indian hydrogen programme is being supported through the Department of Scientific and Industrial Research (DSIR) and the Ministry of New and Renewable Energy (MNRE). A corpus of Rs 100 crore, funded by the oil companies and Oil Industry Development Board, has been created to fund this initial work.

The challenge is to produce hydrogen at competitive rates, ideally using clean domestic resources and to manufacture buses also at competitive rates.

Fuel cost: The US Department of Energy mandate is to produce hydrogen at a delivered and dispensed cost of \$2-4 by 2020 from fossil fuel and from electrolysis at US\$ 7-9.

Current Indian cost of production of hydrogen using naphtha fuel from Panipat refinery is US\$ 4-5/kg, but delivered cost (with all infrastructure) is expected to be in the range of US\$ 12/kg. This is comparable to current global costs, which range from US\$ 14 in US; US\$12 in Europe and US\$8 in Japan. At this cost, hydrogen is not competitive with conventional fuels (1 kg of hydrogen is equal to roughly 3.8 litres of petrol. But fuel-cell technology is much more energy efficient than combustion engine using conventional fossil fuels (Roughly you get 14 km/kg in fuel cell against 8 km/litre in conventional). So, it is possible that this advantage, combined with economies of scale will bring costs down in the near future.

Another source of hydrogen is from the Chlor-Alkali industry, which produces it as a waste product. The challenge will be to procure this hydrogen at competitive rates for use in vehicles and to build infrastructure for its use.

Bus cost: The cost of fuel cell buses are beginning to get more competitive and clearly will become more so as production increases. The cost of the Indian manufactured bus (Tata Motors) is roughly estimated to be Rs 2 crore; in Europe the price is Rs 2.5 crore and China roughly Rs 1.60 crore. Tata Motors informed EPCA that its key objective is to increase domestic manufacture of certain parts of the bus to bring down costs. But it is clear that globally H-fuel cell bus costs are falling and will soon be in the same range of E-buses (*EPCA report no 86 has found that the cost is between Rs 75 lakhs to Rs 1.75 crore for E-buses*)

3. Regulatory challenges in India for hydrogen-fuel cell buses

To progress beyond the 'demonstration' phase, India needs to bring in regulatory changes to promote hydrogen-fuelled cell buses:

1. The Ministry of Road Transport and Highways (MoRTH), which has now given permission to two buses to ply in Haryana, must make permit conditions for these buses.
2. The Petroleum and Explosives Safety Organisation (PESO) must bring regulations for dispensing hydrogen fuel (currently only permission is to dispense for demonstration purposes in IOC Campus in Faridabad)
3. The Bureau of Indian Standards (BIS) must develop and issue specifications of hydrogen as a fuel.

This work must be expedited. The Government of India should specify, which ministry will be responsible for the country's hydrogen programme and its timelines to ensure that it can ramp up production of hydrogen and manufacture of buses.

4. H-CNG—a quicker option to clean fuel

Even while India continues to work to bring hydrogen fuel cell buses at competitive rates into the country, there is another pathway for the use of hydrogen to get cleaner vehicles.

The IOC R&D Centre has brought to EPCA's attention its work on developing a patented technology for compact reforming process – a process in which piped natural gas is reformed to be mixed with hydrogen.

This technology, called H-CNG – hydrogen CNG – is gaining popularity worldwide. Worldwide hydrogen is being blended (20-30%) with natural gas and then compressed to dispense into vehicles. US, Brazil, Canada, South Korea have all conducted trials and find that they get reduction in emissions from buses using H-CNG.

The IOCL R&D Centre's Compact Reforming Process takes the technology steps ahead. In H-CNG projects the challenge is to set up the infrastructure to pipe and transport hydrogen gas in order to physically mix it with CNG. This is a logistics problem and has safety concerns.

The IOCL R&C Centre's technology overcomes this logistics challenge. The Compact Reforming Process is a machine, which partially reforms natural gas to directly produce hydrogen-CNG mixture in the desired proportion. The process is flexible, the machine can be installed at the location where the gas is available and it allows for production of H-CNG as per the demand.

The gaseous H-CNG (ideal mixture is 18% Hydrogen in CNG) can be directly used as automobile fuel after compression.

Status/tests on H-CNG till date

The Niti Aayog-CII Action Plan for Clean Fuel, published in 2018, also recommends that H-CNG is an alternative fuel that will utilise the existing piped gas infrastructure in Delhi. It recommends that a demonstration of this technology at a bus depot should be set up. It also lists the regulatory policies to facilitate the induction of this technology:

- a. Notification of H-CNG as an automotive fuel (draft notification issued on July 17, 2018);
- b. BIS to issue standards for use of H-CNG as a fuel
- c. PESO for issue clearance for H-CNG storage cylinders on vehicles (Tests have already been conducted and results submitted).

The Ministry of Road Transport and Highways (MoRTH) has issued a draft notification on July 17, 2018 to include H-CNG as a fuel in the Motor Vehicles Rules 1989.

ARAI and IOCL have carried out tests on 6 CNG heavy duty engines using H-CNG (18% mixture) and has found that the engine has passed the endurance tests; had improvement in performance and that no visible was found in the workings of the engine.

EPCA believes this technology is extremely promising as it can be set up in different locations – at petrol pumps for instance, or bus depots. It is an intermediate but important step in our transition towards a hydrogen economy.

The most promising aspect of this technology is that it will allow for the utilisation of the existing infrastructure of CNG – buses as well as the piping network and dispensing station. Therefore, it can be seen as the next-gen CNG for cleaner air.

5. H-CNG advantage in emissions and road map for implementation

IOCL R&D Centre has set up this natural gas compact reformer for H-CNG production (H-compactor) at its facility in Faridabad.

Using H-CNG (18% mix of hydrogen) CNG-engine (BS IV) has been tested by the ARAI-Pune to understand the emission reduction using H-CNG as compared to 'neat' CNG.

The results (see graph below) find the following:

70% reduction in CO emissions

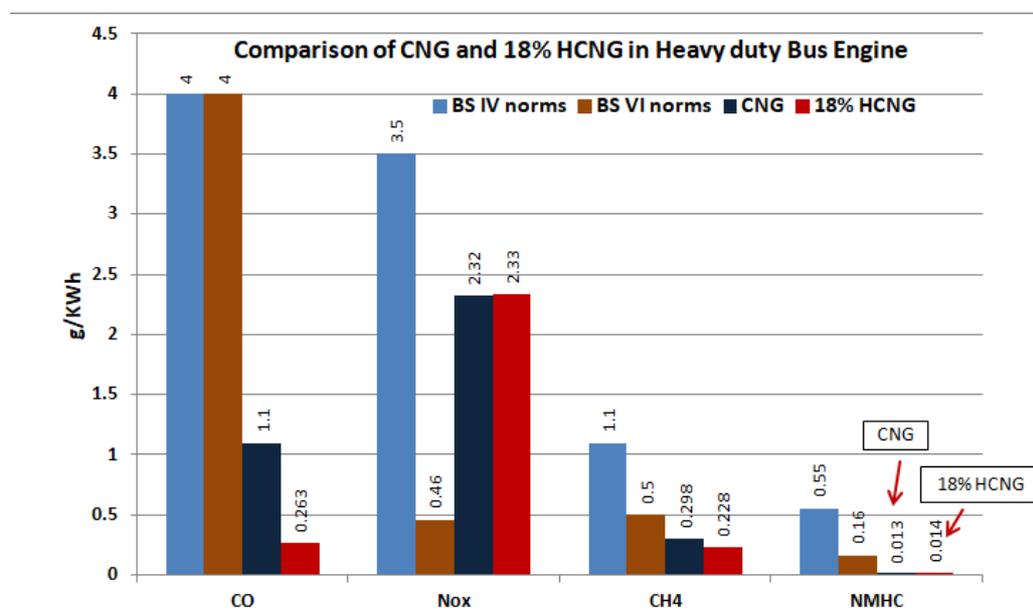
15% reduction in total hydrocarbon

No reduction in NOx (same as CNG)

4-5% improvement in fuel economy

The comparison with BS VI norms also shows that H-CNG will improve the performance of CNG in all respects, other than NOx.

To meet BS VI emission norms by 2020, NOx emission controls will have to be put into vehicles, using after-treatment devices, as is done in diesel vehicles.



In other words, Delhi, which has invested in CNG buses and infrastructure, can now use this next-generation technology to bring even lower emissions and at scale and speed.

In EPCA's view this would be an important next milestone after CNG if implemented at scale and speed. In this option, the current CNG bus infrastructure can be used; and current and new CNG buses (BS VI) using H-CNG will give much lower emissions, with NOx controls.

6. Costs of H-CNG deployment in Delhi

EPCA requested IOC R&D Centre to work out the economics for use of H-CNG in all buses of Delhi – cost of setting up the H-Compactor and cost of running the bus using this hydrogen-mixed fuel.

The estimates are that to fuel 5,500 buses (current fleet) it would require some 400 tonnes of H-CNG per day.

As it is important to set up infrastructure to dispense H-CNG in different locations it would require 4 plants of 100 tonnes per day.

The capital cost of these 4 H-Compactor plants is estimated to be Rs 330 crore.

The fuel cost is estimated to increase by Rs 0.75/km compared to 'neat' CNG.

Clearly, the costs are not prohibitive and if further work can be done to reduce NOx emissions, then this approach – an intermediate hydrogen technology approach can be scaled up and implemented across the full bus fleet in the city within 2-3 years.

7. EPCA's recommendations for the consideration of the Hon'ble Court

Based on the above examination of issues, EPCA would recommend a two-phase approach to hydrogen-vehicle economy in the country.

First, to take key decisions/bring regulations to support a scaled-up hydrogen-fuel cell economy, which focuses on critical segments like buses.

Second, to use H-CNG as an intermediate solution, which will make full use of Delhi's transition to CNG and provide a further improvement in emission performance of its buses.

To implement this approach, EPCA would like to put forward the following directions for the consideration of the Hon'ble Court:

A. To implement a full hydrogen economy for key vehicle sector programme

Currently, the Indian Hydrogen-Vehicle programme is confined to demonstration and small pilot projects. The following is needed before any further decisions can be taken:

1. The Ministry of Road Transport and Highways (MoRTH), which has now given permission to two buses to ply in Haryana, must make permit conditions for these buses.
2. The Petroleum and Explosives Safety Organisation (PESO) must bring regulations for dispensing hydrogen fuel (currently only permission is to dispense for demonstration purposes in IOC Campus in Faridabad)
3. The Bureau of Indian Standards (BIS) must develop and issue specifications of hydrogen as a fuel.

We would recommend that the Hon'ble Court could consider directing the Government of India to finalise its plan for Hydrogen Fuel Cell vehicles, including schedule for bringing supportive regulatory changes to facilitate the growth of this programme.

B. To implement a scaled-up H-CNG programme in Delhi

In this case, EPCA would recommend the following directions:

1. **MoPNG/IOCL R&D Centre with IGL and Delhi transport department be directed to give a plan for use of H-CNG in the entire bus fleet of the city, with a phased in schedule (including demonstration and tests to reduce NOx emissions). This schedule should provide for all steps to be taken within a period of 2-3 years. The objective should be to bring in H-CNG with NOx controls for entire public transport system of buses by 2020-2021.**
2. **The H-CNG plan, after review by the Hon'ble Supreme Court, could be supported through the Environment Compensation Charge (ECC) funds.**