Fuel Cell Electric Vehicle (FCEV)

Defining characteristics	*Narrative*
General	Worldwide, most light- and heavy-duty vehicles are powered by internal combustion engines (ICEs) that run on energy-dense fuels such as petrol, but a small proportion of the vehicle population operate on an entirely different principle, that is, the conversion of electrical energy to mechanical power. There are two primary options for all-electric vehicles: batteries or fuel cells with potential to substantially reduce the carbon footprint of the transport sector . By the nature of their electrochemical reaction, fuels cell can be more than twice as efficient as an ICE (Thomas, 2009). Major milestones in fuel cell technology[101] include their inaugural use in the US Apollo Space Program in the 1950s, and development of a working prototype of a fuel cell electric vehicle (FCEV) by General Motors in the mid-1960s. In decades since then, research and development (R&D) efforts, driven by climate change and energy security policy imperatives, have focused on addressing conversion efficiency, cost, cycle life and safety issues.. Today, hydrogen fuel cell electric vehicles (FCEVs) are recognised as being highly energy efficient and considered for their suitability as passenger and haulage vehicles in national road fleets. The main benefits to FCEVs are its competitive travel range, high energy efficiency and very low to zero tailpipe emissions (Kobayashi et al., 2009; Chan, 2007; Colella et al., 2005).
Siting and land use	Not relevant
Design (components) and Operation	Except for external features such as a charging port, FCEVs sold on today's automotive market have the same generic form, steering controls and appliances as ICE vehicles. Similarly, a FCEV uses a regenerative braking system to recharge a high capacity battery when its brakes are applied, which battery provides supplemental power when needed. Essentially, a functional FCEV has four distinctive components: 1) an energy storage unit; 2) a power generation unit; 3) a control unit; and 4) a propulsion unit. These work in synergy with reactant flow, heat and temperature control, and water management system components. An auxiliary battery provides supplemental power to motor during vehicle acceleration. The energy storage unit is a pressurised fuel tank for hydrogen, or other organic gases (methane or natural gas), or biofuels (methanol), which gases are converted by the power generation unit into electricity. The vehicle's onboard power generator unit is a fuel cell stack, made up of hundreds of fuel cells assembled together using bipolar plates that produces electricity, water and heat, directly from a fuel gas and an oxidant. The fuel cell stack is connected the FCEV's power control unit, supply and return lines from the fuel gas tank, an air supply, and external environment (Ahluwalia et al., 2004). A power control unit or controller provides intelligent energy management; regulating power and supplying either variable pulse width direct current (DC) or variable frequency and variable amplitude alternating current (AC), depending on the type of onboard motor and driving conditions. As power is continually drawn from the fuel cell stack to meet transient energy demands, the controller also receives and processes signals from the vehicle's reactant flow,[102] heat and temperature control,[103] water

[101] Fuel cells are devices that transform chemical energy encompassed within a fuel directly into electricity. Individual fuel cells which produce about 1 volt are connected in series to form a battery (of different shapes and sizes) for mobile or stationary applications.

[102] hydrogen and oxygen inlet and outlet flow rates

	management subsystems, thereby actuating corresponding pump and valve controls to satisfy performance, safety and reliability standards (Larminie and Dicks, 2003; Pukrushpan, 2003). The propulsion unit comprising an electric motor and integrated power electronics converts electrical energy into mechanical energy that turns a drive ***axle*** transmitting full torque to the FCEV wheels. In some FCEV designs, electric motors[104] are installed inside wheels instead of a central position on the drive axle. When a FCEV contactor is switched on, hydrogen from the pressurised storage tank(s) is inducted at the negative pole (anode) of the fuel cell where inflowing gas atoms are ionised with the help of a (platinum) catalyst, generating electricity in a circuit linking the negative and positive poles of the fuel cell, and water (vapour) and heat at the positive pole (cathode) of the fuel cell.[105] Excess/unused hydrogen is recycled to fuel tank(s) and water vapour evacuated through a tailpipe. Current from the fuel cell stack is routed to the onboard motor by the controller with or without conversion into AC with an in-built set of transistors, depending on the type of electric motor installed. Inside the electric motor, current flows to a set of brushes that transmit current to a commutator connected to an armature coil and output shaft. Concomitantly, current flow from the controller energises a rotor coil which produces a rotating magnetic field. In their energised states, current in the armature interacts with the magnetic field producing a rotational motion of output shaft. To this effect, the more electric power the motor receives, the faster it can turn the drive **axle** that transmits power to the wheels.
Cost	The cost of FCEVs is related to many variables including primarily performance-related specifications such as travel range, top speed, and power consumption. Brand names and production volume of this emerging technology also influences cost price. In general, FCEVs are more expensive than other vehicles, but price differences are likely to narrow down as the technology gains maturity and market share. Citing various studies, Eaves and Eaves (2009) report vehicle costs ranging between USD23,000 and USD29,000 for an FCEV delivering 100kW at peak power. Fuelling costs are estimated at USD1.00/kWh, 46% higher than that of battery-powered electric vehicles (BPEVs). However, these estimates appear outdated and over-optimistic. Toyota's Mirai, a 4-door sedan outfitted with a fuel cell-powered 113kW electric motor, with a first production run of 700 vehicles, is priced at JPY6.7 million (USD57,400) before expected Japanese government subsidy of JPY2 million (US$19,600) takes effect. In Germany, Germany starts significantly higher at €60,000 (US$75,140).[106] Honda's FCX Clarity powered 100kW electric motor sells for USD50,875.[107]

Oxygen required for a fuel cell comes from air that is pumped into the cathode to increase power generated. Larminie and Dicks (2003) show how hydrogen and oxygen flow rates can be determined analytically, enabling control over flow rates using advanced micro-processors.

[103] coolant flow rate and temperature

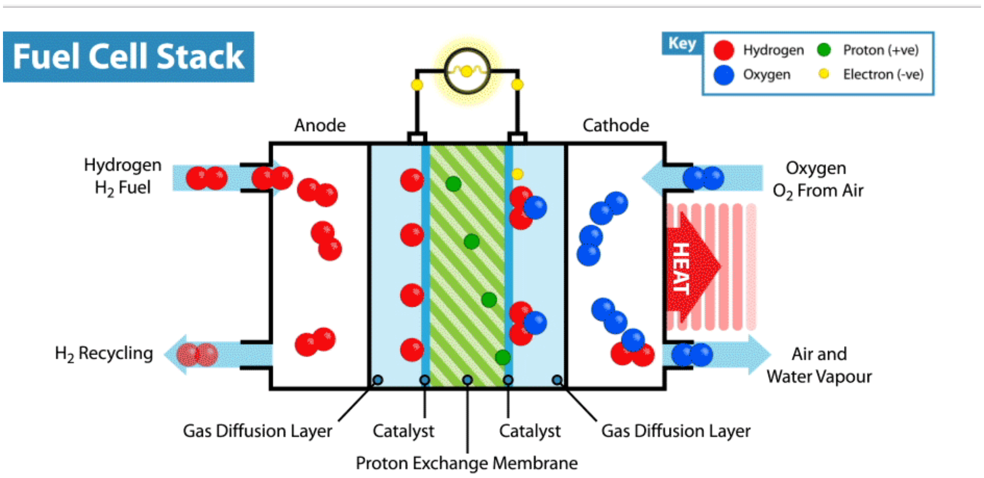
[104] There are four types of motors: synchronous, repulsion, universal, induction motors. Induction motors are more widely used because of their simplicity, low cost,, ruggedness, wide speed range and absence of back electromotive force (Chan, 2007)

[105] A fuel cell (FC) consists of an anode, a cathode and electrolyte sandwiched between the two. Its electrolytic proton exchange membrane acts as an electron barrier and proton carrier, forcing free electrons from H_2 to flow through a circuit from the anode to the cathode thus generating an electric current.

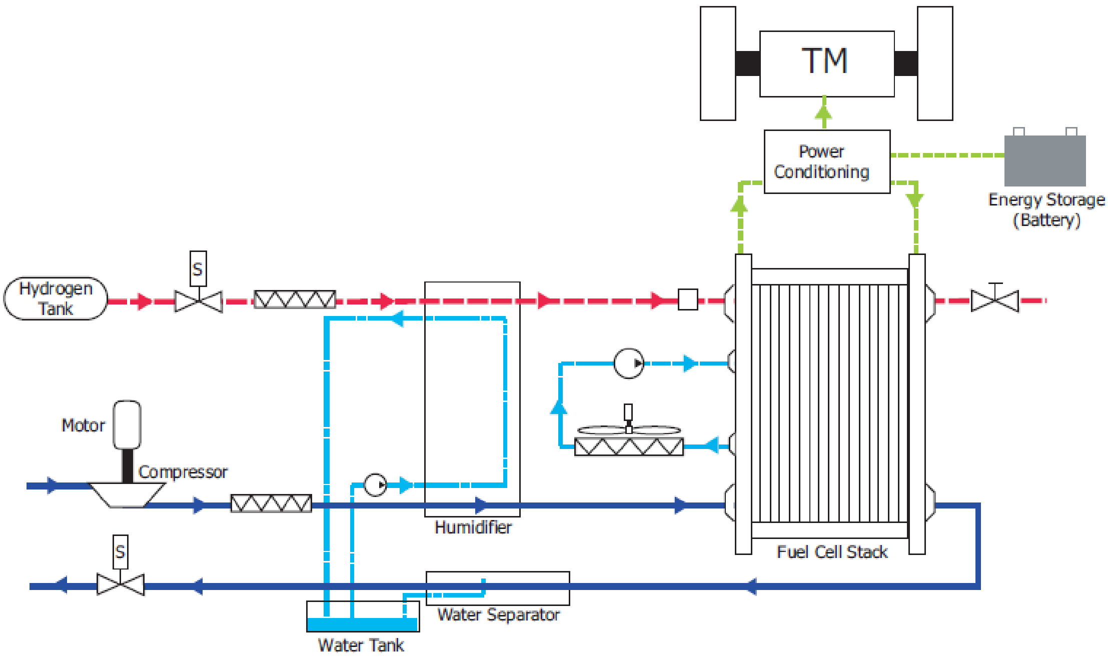
[106] https://en.wikipedia.org/wiki/Toyota_Mirai

[107] http://www.caranddriver.com/hyundai/tucson-fuel-cell

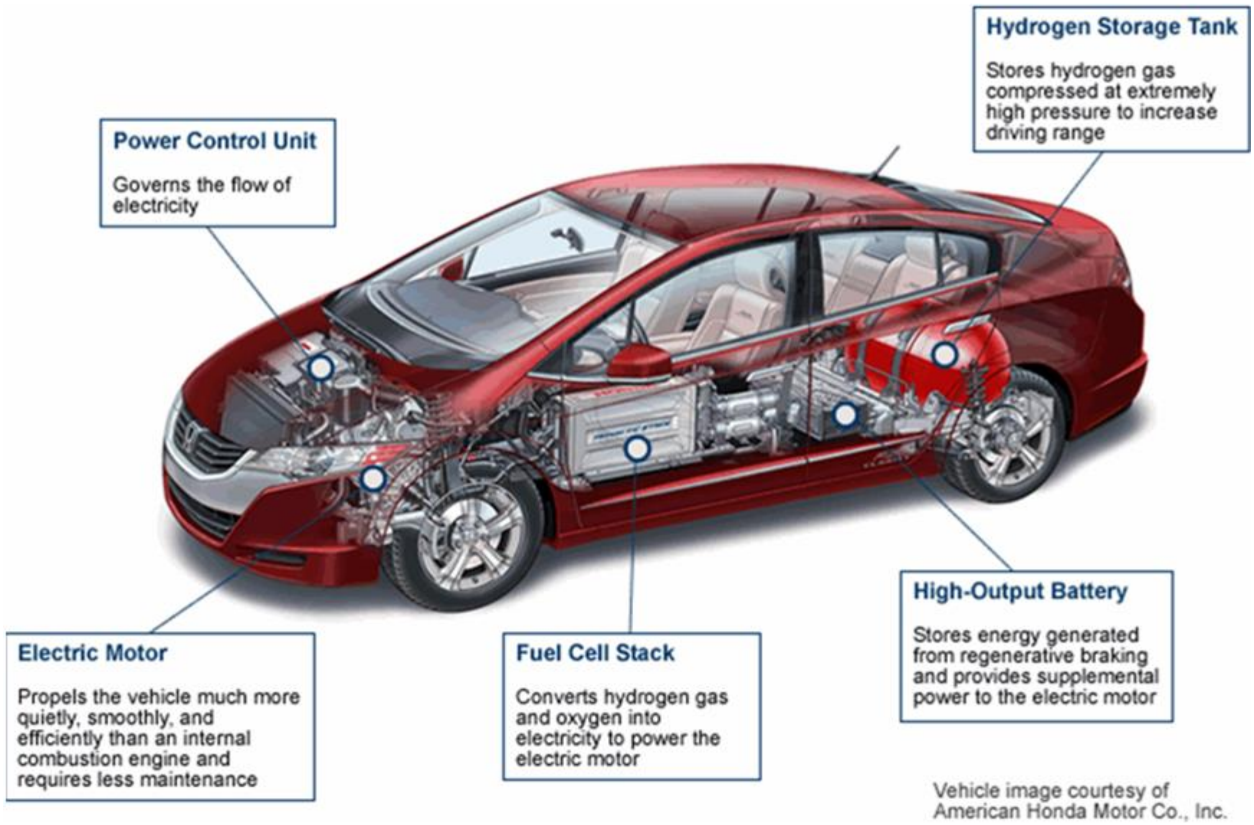
Supporting infrastructure	Fuelling infrastructure High quality roads
Advantages	High energy conversion efficiency compared to ICEs (Colella et al., 2005) Very low chemical and acoustical pollution (Chan, 2007) Fuel flexibility Rapid load response with satisfactory driving range
Disadvantages /Challenges	Initial and life-cycle costs with respect to conventional vehicles Underdeveloped hydrogen infrastructure (Thomas, 2009), although fuel processors currently under active development are capable of turning hydrocarbon or alcohol fuels into hydrogen, and consequently making this problem redundant FCV drivetrain costs remain at least an order of magnitude greater than internal combustion engine drivetrain costs (Kobayashi et al, 2009; Chan (2007)
Abatement potential	Depending on the primary source and production pathway of hydrogen used in FCEVs, Colella et al. (2005) report GHG and particulate emission reductions of 1 to 23% when hydrogen fuel is derived from coal and wind, respectively. Compared to ICE vehicles powered by gasoline, Kobayashi et al. (2009) report a 50 to 60% reduction in well-to-wheels (WtW) CO_2 emissions from FCEVs. Tank-to-wheel (TtW) emissions reduction is simply the foregone emissions by vehicles powered by internal combustion engines (ICEs) running.
Level of penetration	FCEVs are a completely new technology



Source: http://www.intelligent-energy.com/static/img/animations/fuel_cell_stack.gif



Source: Pukrushpan, J.T., 2003.



Source: http://www.intechopen.com/source/html/18666/media/image12.png

Source: https://www.youtube.com/watch?v=98EmzYK75QM

Further reading

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