The applications of Fuel Cell in transportation
(Vehicle in general and Bus in special)

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Introduction

- Fuel cell vehicles hold the promise of high efficiency and zero or near-zero emissions.
- High efficiency fuel cells have the potential to deliver comparable power, range and performance to today's conventional vehicles.

Introduction of public transportation of Vietnam

- The rapidly increasing of population in the big cities causes the increasing of the amount of vehicle.
- The development of infrastructure can not satisfy this problem.
- The government tries to solve this problem by encouraging public transportation such as train, coach, bus.
- The quantity of public transportation in Vietnam is increasing rapidly.

Why we should change from traditional fuel to fuel cells

- Natural resources preservation
- To conserve the environment
- The petrol price is increasing day by day

General concepts

- The emission of vehicles is one of the main causes of pollution, greenhouse effect.
- The consumption of vehicle is one of the main causes of the rapid exhaustion of the petroleum resources.
- Hence, almost all the countries in the world approved regulations to reduce emissions (particulate matter (PM) and oxides of nitrogen (NOx)) from transit buses through use of advanced technologies.

General concepts

- These technologies include alternative fuel buses, zero emission bus technologies (include battery electric, electric trolley, and fuel cell).

Objectives and goals

Our objectives and goals are to change from traditional fuel to fuel cell in transportation. Hence, the new one must fulfill:

- Safe, reliable, efficient, and cost effective operation of fuel cell buses.
- Fueling infrastructure for this new one.

Choices of Fuel Cell Types for transportation

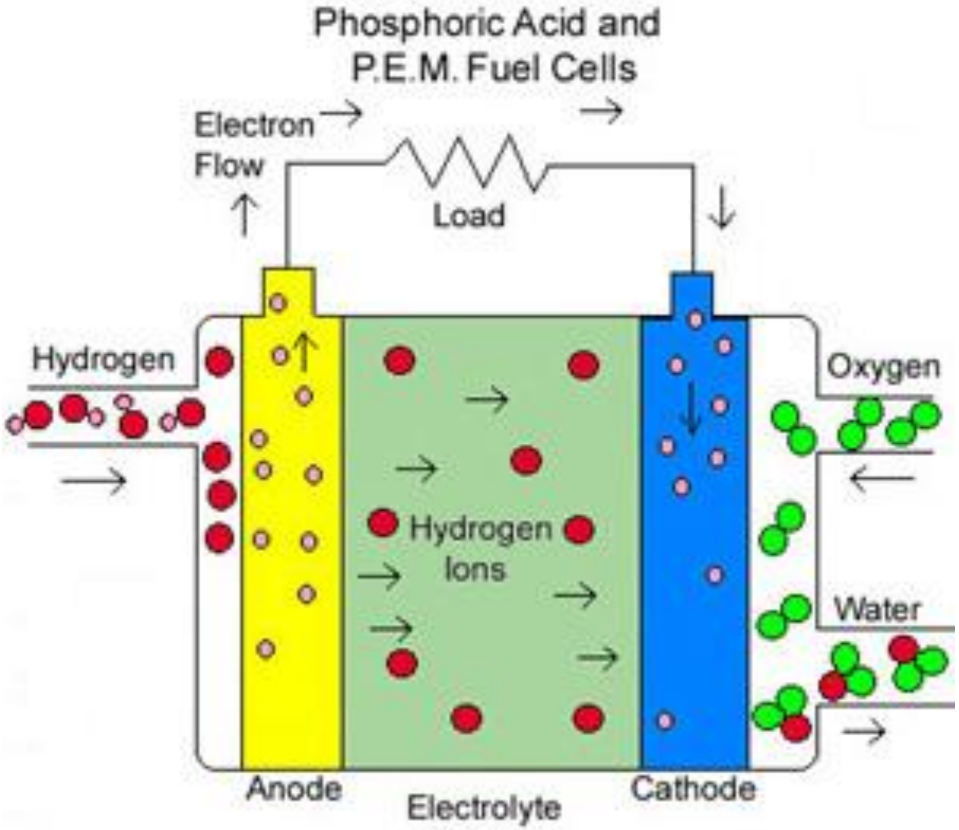
- One researcher stated, *"It is unlikely that there will be a newly developed fuel cell type. The development period is simply too long…if fuel cells work at all, it will be PEM."*
- One auto manufacturer stated: *"It's PEM…the others aren't viable for reasons of cost, durability, and operating temperature."*
- The key reasons cited for PEM include its low operating temperature, and shorter warm-up and start-up times. Also offering the greatest potential for the kind of cost reductions.

Choices of Fuel Cell Types for transportation

TYPES OF FUEL CELLS

	Temp. °C	Application
• Alkaline (AFC)	70-90	Space
• Phosphoric Acid (PAFC)	150-210	Commercially available
• Solid Polymer (PEMFC)	70-90	Automotive application
• Moltan Carbonate (MCFC)	550-650	Power generation
• Solid Oxide (SOFC)	1000-1100	Power generation
• Direct Methanol (DMFC)	70-90	Under development

Choices of Fuel Cell Types for transportation



Choices of Fuel Cell Types for transportation

- Other possible technologies include direct methanol, solid oxide, molten-carbonate, and alkaline.
  - Direct methanol was observed to be better suited for small portable devices and battery replacement.
  - Solid oxide was offered as a possibility for passenger and transit vehicles; however, this technology has technical properties (high operating temperatures and long warm-up time) that make it better suited for stationary applications than transportation.

Choices of Fuel Cell Types for transportation

- Molten carbonate was described as being viable for trains and ships.
- Alkaline fuel cells offer high efficiency that makes them suitable for aerospace applications.

Fuel Choices

- A fundamental problem with fuel cell technology whether to store hydrogen or convert it from other fuels on-board the vehicle.
  - Direct hydrogen is the approach most favored because of its higher efficiency and zero emissions but it has significant storage problems.
  - On the other hand, methanol, ethanol, and gasoline offer the advantages of liquid fuels, but require on-board reformers to convert the fuel to hydrogen.

Direct hydrogen

- Approximately 40 million tons of hydrogen gas are produced annually on a global scale, but very little of this is used as an energy source.
- The ability to use hydrogen directly in a fuel cell provides the highest efficiency and zero tailpipe emissions.
- However, hydrogen has a low energy density and boiling point, thus, on-board storage tends to be large and heavy.

Direct hydrogen

- There are three types of hydrogen storage under development: compressed hydrogen, liquefied hydrogen, and binding hydrogenate to solids in metal hydrides or carbon compounds.

Direct hydrogen

Fuel	Gasoline	Compressed Hydrogen	Liquefied Hydrogen	Metal Hydrides
Energy (MJ)	1,408	664	664	664
Fuel Weight (kg)	29.5	4.7	4.7	4.7
Tank Weight (kg)	13.4	63.3 – 86	18.6	120
Total Fuel System Weight (kg)	43.2	67.9 – 90.5	23.3	125
Volume (liters)	40.1	409 – 227	178	120
Vehicle Range (km)	600	600	600	570
Development Status	Commercial	Commercial Prototype	Initial Prototype	Initial Prototype

Source: NAVC, “Future Wheels,” November 2000.

Compressed Hydrogen

- Compressed hydrogen offers the least expensive method for on-board storage of hydrogen.
- However, high pressure requires the high pressure withstand of tank, cables.
- Light-duty vehicles have trouble with the size. But heavy-duty vehicle such as bus dose not.

Liquefied Hydrogen

- Liquefied hydrogen does not have the high storage size and weight penalty as compressed hydrogen, but it is still bulkier than gasoline storage.
- Require of maintaining the extreme cold temperature (-253°C) during refueling and on-board storage currently poses a great technical challenge.

Hydrides

- Use materials that absorb hydrogen into their crystal structure (metal hydrides).
- Heat is required to release the hydrogen
- → Hydride systems avoid safety concerns surrounding compressed or liquefied hydrogen.
- However, the metal compounds used to attract hydrogen tend to be very heavy resulting in only 1.0 to 1.5 percent hydrogen by weight.

Methanol

- Several automakers are using methanol to power fuel cells.
- If 10 percent of offshore flare gas was captured and converted to methanol, it would supply 9.5 million fuel cell vehicles annually.
- The disadvantages concern about methanol toxicity, which can result in blindness or death if ingested. It can also enter the body through contact with the skin.

Ethanol

- Ethanol is a renewable resource
- Ethanol is considered less toxic than either gasoline or methanol.

Gasoline

- Using reformers for on-board extraction of hydrogen from gasoline is one approach to commercialization of fuel cell vehicles, since the gasoline infrastructure is already in place.
- However, producing hydrogen from gasoline in a vehicle system is much more difficult than from methanol:

Gasoline

- The reformation reactions occur at 850°C to 1000°C
- Furthermore, there is concern about the sulfur levels in current gasoline and carbon monoxide in the reformer effluent poisoning the fuel cell.

Fuel Choices

In general, fuel-reforming technology requires complex integration of all the components into a compact, lightweight, efficient, and low-cost system. The key is to couple the various systems together, some of which generate heat and others use heat, to carefully optimize the heat and energy economics. On-board reforming systems currently suffer from packaging issues, extra weight, complicated controls, and high cost.

Fuel cell vehicle design challenges

- Higher temperature operation, better power-train density, water management, precious metals content, compatibility with environmental conditions, start-up time, and system life, cost.
- Thermal/Air/Water Management
  - Heat rejection
  - Compressor size, weight, turndown

Fuel cell vehicle design challenges

- On-Board Fuel Processing
  - Size/Weight
  - Start-up/Transients
  - Catalyst durability
  - Fuel issues
  - CO clean-up
- Efficiency
  - Higher cell voltage
  - Cathode activity
  - Fuel processor start-up