OVERVIEW OF ALTERNATIVE TRANSPORTATION FUELS

[1]**P H Shukla, [2] Y S Patel**
[1]Lecturer , [2]Lecturer
shuklapurvi@gmail.com yaminipatel2016@gmail.com
[1]Chemical Engineering Department,
[1]Government Polytechnic Gandhinagar
[1]Gandhinagar, India

Abstract: The global reliance on traditional fossil fuels for transportation, primarily gasoline and diesel, presents significant environmental and economic challenges, including climate change, air pollution, and geopolitical instability. the critical need for and the state of alternative fuels for the transportation sector, a field driven by concerns over energy security, air pollution, and climate change. This has encouraged an intensive search for viable alternatives to transport fuels. This abstract provides an overview of the key alternative fuels and technologies, examining their potential to displace conventional petroleum products. As the global dependency on fossil fuels, particularly petroleum, presents significant environmental and geopolitical challenges, the search for viable alternatives has intensified. This review categorizes and discusses the various alternative fuel types,

In conclusion, the transition away from conventional fossil fuels is essential for achieving a sustainable and secure future. While no single alternative fuel is a silver bullet, a diverse portfolio of solutions, supported by strategic policy, technological innovation, and infrastructural investment, is required to meet the varied demands of different vehicle types and transportation sectors. The future of transportation will likely be characterized by this mosaic of fuels, each playing a vital role in mitigating environmental impact and enhancing energy resilience

Index Terms: **Alternative Fuels, Fuel, alternative of transportation fuel**

1. INTRODUCTION

With the stock of fossil fuels diminishing throughout the world and demand for energy-based comforts and mobility ever increasing, time is ripe that we strike a balance between energy security and energy usage. Moreover, having uplifted to such a sphere of engineering excellence, reverting back to the ages of the bull carts will prove next to impossible thereby compelling us to search for a basket of alternative fuels to derive energy to cater to our needs. Several sources of energy, especially for driving the automotives are being developed and tested. Judicious utilization of this basket of energy is the call of the hour for a nation to see itself through the tough days ahead.

Today's engine development is heavily controlled by increasingly stringent emission legislation, leading to rapid developments. The EEV (Enhanced Environmentally Friendly Vehicles)-standards is coming into force for polluted cities, creating an extra incentive for the development of extra clean vehicle technology. The future of gaseous/alternative fuels depends on the maximum of polluting emission allowed, the technology available and the cost of concepts developed. Promising developments are taking place in the area of the conventional prime mover, the diesel engine.
At the end of the day the concept that fulfils all legislative requirements and can be sold at the lowest price will be the winner. And that may be an engine running on a conventional or on an alternative fuel or most likely on both.

The alternatives to petroleum-based fuels must meet the following criteria, if they are going to be used widely for transportation.
- Technical acceptability
- Economically competitive
- Environmentally acceptable
-Safety & availability.

Based on the above criteria, several alternate fuels have been considered from time to time all over the world as low-cost substitutes for gasoline and diesel. Lately they have gained importance as clean fuels. The prominent among these are, biodiesel, electric fuel, ethanol, hydrogen, methanol, natural gas (CNG/LNG), propane (LPG), DME, P-series and solar fuels.

2 ETHANOL [1,6]

Ethanol (ethyl alcohol, grain alcohol, EtOH) is a clear, color less liquid with a characteristic, agreeable odor. In dilute aqueous solution, it has a somewhat sweet flavor, but in more concentrated solutions it has a burning taste. Ethanol (CH3CH2OH) is a group of chemical compounds whose molecule contains a hydroxyl group, -OH, bonded to a carbon atom. Ethanol made from cellulosic biomass materials instead of traditional feedstocks (starch crops) is called **bio-ethanol.**

The Clean Air Amendments of 1990 mandated the sale of oxygenated fuels in areas with unhealthy levels of carbon monoxide. Since that time, there has been strong demand for ethanol as an oxygenated blended with gasoline. In the United States each year, more than 1.5 billion gallons are added to gasoline to increase octane and improve the emission quality of gasoline. In some areas ethanol is blended with gasoline to form an E10 blend (10% ethanol and 90% gasoline), but it can be used in higher concentrations such as E85 or in its pure form.

2.1 Production

The production phases in Ethanol production are shown in the following line diagram (Fig-1):

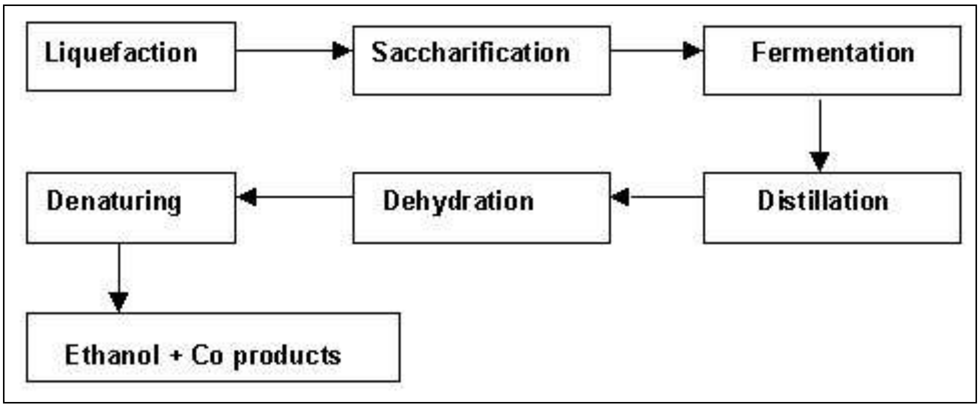


Figure-1: Ethanol Production Process [6]

Fuel ethanol is denatured with small amount (2%-5%) of some product such as gasoline, to make it unfit for human consumption. Two main co products of ethanol production are CO2 and distillers grain. Many ethanol collect the CO2, clean it of any residual alcohol, compress it and sell it for use in carbonate beverages or to flash freeze meat.

2.2 Emissions Characteristics:

Emission results of a test conducted by National Renewable Energy Laboratory (NREL), USA are given in the following table. The test was conducted on Taurus 1998 model with both E85 and gasoline RF-A (industry average gasoline). Table-1 shows the comparative emissions from ethanol and gasoline fuelled vehicle.

Emissions of total potency weighted toxics (including benzene, 1-3,butadiene, formaldehyde, and acetaldehyde) for the E85 were 55% lower than that tested on gasoline

A recent Australian study with E10 gives the following emission results:

-Decreased emissions of CO by 32%.

-Decreased emissions of HC by 12%.

- Decrease in non-regulated toxics: 1-3 butadiene decrease by 19%, benzene decrease by 27%, toluene decrease by 30% and xylene decrease by 27%.
- Increase in non-regulated toxics: acetaldehyde increase by 180% and formaldehyde increase by 25%.
- 1% increase in NOx

Recent Australian life-cycle analysis work has revealed that E10 blends are considered greenhouse neutral. The same study revealed that E10 decreased tail pipe emissions of hydrocarbons and NOx (25% and 15% respectively), but particulates (PM10) remained unchanged.

Emissions in g/mi	AFV-Ethanol	Gasoline
NHMC	0.10	0.10
CO	1.48	1.13
NOx	0.12	0.09
CO_2	396.4	439.7

Table-1: Comparative Emissions (Ethanol Vs. Gasoline) [6]

2.3 Advantages of Ethanol:

Some of the advantages of Ethanol as an automotive fuel are:

- It reduces our dependence on imported fuels.
- It reduces air pollution.
- Ethanol is renewable.
- Refuelling is akin to that of gasoline or diesel.
- Is applicable for both light and heavy-duty vehicles.
- More energy density compared to gasoline with optimized compression ratio.
- Maintenance assistance required is more or less identical to that of conventionally fueled vehicles.

2.4 Disadvantages of Ethanol:

- Demands frequent refuelling keeping the volume of the tank unaltered.
- Use of special compatible lubricants required.
- Ethanol, especially E85 requires special replacement parts.

2.5 Operation and Performance:

- High energy density compared to gasoline.
- No loss in power, acceleration and payload.

- Special lubricants are required.
- Special parts required.

It is estimated that the US automakers have about 250,000 light-duty E85 vehicles on the road by the year 2000.

2.6 Storage & Distribution:

Storage and distribution of ethanol is quite similar to that of gasoline and diesel. E95 is available only through bulk suppliers.

3.0 METHANOL [1,9,15]

Methanol (CH3OH) is an alcohol fuel. Methanol is methane with one hydrogen molecule replaced by a hydroxyl radical (OH). The alternative fuel currently being used is M-*%. In the future, neat methanol or M-100 may also be used. Methanol is also made into ether, MTBE, which is blended with gasoline to enhance octane and to create oxygenated gasoline. Methanol contains no sulphur or complex organic species.

3.1 Production:

Methanol can be produced from a verity of feedstock, including natural gas, coal, biomass and cellulose. It is predominantly produced by steam reforming of natural gas to create a synthesis gas, which is then fed into a reactor vessel in the presence of a catalyst to produce methanol and water vapour. Infect today's economics favor its production from natural gas.

3.2 Emissions:

Methanol perhaps is not the cleanest gasoline alternatives but it has a distinct advantage in controlling ozone formation. USA is focused to methanol and methanol blends as it promises significant ozone improvements and control smog formation at a reasonable cost.

The following table (Table-2) gives emissions comparison between gasoline, M85 and M100.

Emissions, mg/km FTP cycle	Gasoline	M85	M100
THC	161.59	111.87	124.30
CO	733.37	683.65	870.11
NOx	490.99	379.12	285.89
Evaporative emission (mg/test) FTP test	1720.00	680.00	880.00
Benzene	7.79	4.38	0.32
Toluene	33.66	8.66	2.11
Buta-1-3-diene	0.19-0.50	0.44	2.05
Formaldehyde	4.78	13.87	21.76
Acetaldehyde	0.94	10.02	0.27

Table-2: Emissions form gasoline, M85 and M100 in a FTP Cycle [15]

3.3 Advantages of Methanol:

Some of the advantages of methanol when used as a fuel are:
- Methanol has very lower ozone forming potential.
- Emissions of sulphur and sulphur compounds are virtually negligible.
- Very low evaporative emissions due to its low vapour pressure.
- Easy refueling.
- Methanol is the most practical carrier of hydrogen to run fuel cells.
- Methanol has high-octane quality.

3.4 Disadvantages of Methanol:

The disadvantages of methanol include the following:
- High formaldehyde emissions.
- Acute toxicity.
- Availability is much dependent on the availability of natural gas.
- Low energy content compared to gasoline.
- Demands special lubricants and spare parts.
- May be costly.

3.5 Operation & Performance:

- Because of low energy content, mileage will be slightly lower.
- Power, acceleration and payload are comparable to those of equivalent internal combustion engines.
- Methanol needs special lubricants.
- Compatible replacement parts are required.

Methanol is mostly used in light-duty vehicles. More than 20,000 M85 flexible-fuel vehicles are in operation in USA.

3.6 Safety Issues:

Methanol may not give rise too much safety concerns when used as automotive fuel but it is inherently toxic. Adequate training is required to operate and maintain methanol-fueled vehicles. Moreover neat methanol (M-100) also presents a special safety hazard as it burns without a visible flame and even alcohol-water wastes may be flammable.

3.7 Storage & Distribution:

Toxicity and solubility of methanol in water raises concern for safe storage and distribution. Adequate training is required to store, maintain & operate methanol-fueled vehicles though it has the refueling advantage like gasoline or diesel.

4. ELECTRIC FUEL [9,11,12]

Electricity is unique among the alternative fuels in that mechanical power is derived directly from it, whereas the other alternative fuels release stored chemical energy through combustion to provide mechanical power. Motive power is produced from electricity by an electric motor. Electricity used to power vehicles is commonly provided by batteries, but recently fuel cells are also being explored.

4.1 Battery:

Batteries are energy storage devices. A large number of various types of batteries are being tested for use in electric vehicles. Some of the technologies include lead-acid, nickel cadmium, nickel iron, nickel zinc, nickel metal hydride, sodium nickel chloride, zinc bromine, sodium sulphur, lithium, zinc air and aluminum air. On the other hand fuel cells convert chemical energy to electricity, which then power the motor.

4.2 Fuel Cell:

Day by day fuel cells are becoming the most promising so far as electricity generation is concerned. A fuel cell is an electrochemical energy conversion device. It is two to three times more efficient than an internal combustion engine in converting fuel to power. A fuel cell produces electricity, water and heat using fuel and oxygen in the air. Water is the only emission when hydrogen is the fuel.

4.3 Production:

Electricity is produced from power plants throughout the country, transmitted to substations through high voltage transmission systems, stepped down to lower voltages, and carried to homes and businesses through local distribution systems. This electricity is charged and stored in the onboard rechargeable batteries, which power the motor of the vehicles.

Like battery powered vehicles fuel cell vehicles use on-board electric motor. But while drivers must periodically recharge battery powered vehicles with electricity generated elsewhere, fuel-cell vehicles make their own power from on-board supply of hydrogen, or a hydrogen-rich fuel such as natural gas, methanol, ethanol or gasoline. This enables drivers to fill up at a service station, rather than recharge the car, making it a more practical solution for today's automobiles.

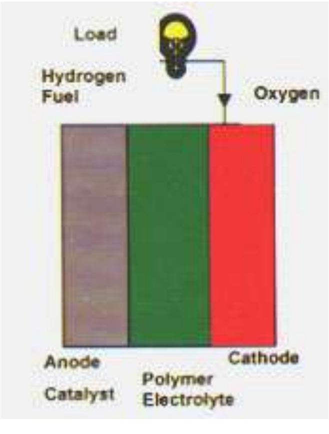
There are six basic types of fuel cells, solid oxide, phosphoric acid, alkaline, molten carbonate, direct methanol and Proton-Exchange Membrane (PEM). The PEM fuel cell has several advantages for transportation use:

- High power density
- Relatively quick start up
- Compact size
- Low operating temperature
- Low noise levels.

4.4 PEM fuel cell components:

A basic fuel cell has three parts: An anode, a cathode and an electrolyte separating the anode from the cathode. In a PEM fuel cell, the electrolyte is a proton-exchange membrane. The fuel (Hydrogen) starts out at the anode and combines with oxygen at the cathode to form water. Since water is in a lower energy state than hydrogen and oxygen by themselves, there is a chemical potential that induces the hydrogen and oxygen to combine into water.

The hydrogen at the anode separates into individual protons and electrons, the constituent particles that comprise hydrogen atoms. A catalyst at the anode helps the separation occur. The membrane allows protons to pass through it, but not electrons.



The proton travel from the anode to the cathod through the membrane. Electrons travel from the anode to the cathode not through the membrane, but through an external device (electrical load). Moving electrons are by definition electricity. The electrons then travel to the cathode, where they recombine with the protons and oxygen to form water.

A full size electric vehicle needs about 50 to 60 KW of power to accelerate and about 12.5 KW of power for cruising. A single PEM fuel cell has about 350 W of power, or 4 W per square inch of the cell area. To supply the necessary power, auto manufacturers may combine 150 and 200 individual fuel cells into a "stack".

Fuel cells require hydrogen to operate, but the storage of hydrogen and availability of hydrogen as a vehicle fuel pose challenges. Because of this, many fuel cell vehicles currently being developed to extract their hydrogen from another fuel, such as methanol or gasoline through the use of an on-board fuel processor or reformer.

4.5 Emissions:

Electric vehicles do not undergo any combustion process. Mechanical power is directly derived from electricity. There are no tailpipe emissions. Water is the only emission when hydrogen is used as the fuel in fuel cells. But the process of commercial hydrogen production to feed the fuel cell is associated with some CO2 emissions.

4.6 Advantages of electric fuel:

The advantages of electric fuel/fuel cells are:
- No tailpipe emissions.
- Vehicles using electric fuel demand less maintenance.
- Electric fuel vehicle have less moving parts to service and replace.
- Acceleration, speed and handling for well-designed vehicles are equivalent to, or better than, those of comparable internal combustion powered vehicles.
- Fuel cells vehicles are highly efficient.
- Fuel cells have high power density.

4.7 Disadvantages of electric fuel:

Some of the disadvantages of electric fuels are:
- Batteries may take time in charging.
- Weather extremes and use of accessories such as air conditioning can affect the range of electric vehicles.
- Noble metal required for some fuel cells thereby increasing the cost.
- Impurities in the hydrogen can hamper cell performance.
- Commercial production of hydrogen to cater to the fuel cells results in substantial copious CO2 emissions.
- Costly technology.
- Limited life of the battery is also a limitation of electric vehicles.

4.8 Operation & Performance:

The main features of operation and performance of electric vehicles are:
- Efficient operation when properly designed.
- Less moving parts demand less maintenance.
- Less noisy while in operation.
- Range spans from 50 to 130 miles depending on the vehicle weight, design and type of battery.
- Decrease in available specific energy in transient driving cycles and decrease in vehicle range with increased speed is reported.
- Sometimes cold weather may drop the specific energy, which the battery can store and hence vehicle range.

4.9 Safety Issues:

When designed properly the electric vehicles are quite safe. The battery or fuel cell stack on-board the vehicles contain enough charge to be fatal, so proper design and grounding should be done.

4.10 Storage & Distribution:

Electric vehicles require charging facilities, which automatically exists with the infrastructure of electricity utility distribution system. Fuels like methanol, ethanol etc. needed for extraction of hydrogen for fuel cells can be obtained from service stations. Installation of equipment at charging locations are expensive and sometimes charging may take much time depending on the remaining state of charge of the batteries and available voltage.

5.0 BIODIESEL [2,3,8]

Biodiesel (mono alkyl esters) is a cleaner-burning diesel fuel made from natural, renewable sources such as vegetable oils. Biodiesel operates in compression ignition engines like petroleum diesel thereby requiring no essential engine modifications. Moreover it can maintain the payload capacity and range of conventional diesel. Biodiesel fuel can be made from new or used vegetable oils and animal fats

5.1 Emission Characteristics:

Biodiesel is the only alternative fuel to have a complete evaluation of emission results and potential health effects submitted to the U.S.EPA under the Clean Air Act Section 211(b). Comparison of emissions from biodiesel and Petro diesel is given in Table3.

Emissions	**B100**	**B20**
Regulated Emissions		
Total Unburned Hydrocarbons	-93%	-30%
Carbon Monoxide	-50%	-20%
Particulate Matter	-30%	-22%
Nox	+13%	+2%
Non-Regulated Emissions		
Sulphates	-100%	-20%*
Polyciclic Aromatic Hydrocarbons (PAH)**	-80%	-13%

NPAH (Nitrated PAHs)**	-90%	-50%***
Ozone Potential of Speciated HC	-50%	-10%
Life-Cycle Emissions		
Carbon Dioxide (LCA)	-80%	
Sulphur Dioxide (LCA)	-100%	

Table-3: Biodiesel Emissions Compared to Conventional Diesel [8]

5.2 Advantages of biodiesel:

The benefits of biodiesel are:

- The lifecycle production and use of biodiesel produces approximately 80% less carbon dioxide emissions, and almost 100% less sulphur dioxide. Combustion of biodiesel alone produces over a 90% reduction in total unburned hydrocarbons, and a 75-90% reduction in aromatic hydrocarbons. Biodiesel further provides significant reductions in particulates and carbon monoxide than conventional diesel fuel.
- Biodiesel is the only alternative fuel that runs in any conventional, unmodified diesel engine.
- Needs no change in refueling infrastructures and spare part inventories.
- Maintains the payload capacity and range of conventional diesel engines.
- Diesel skilled mechanics can easily attend to biodiesel engines.
- 100% domestic fuel.
- Neat biodiesel fuel is non-toxic and biodegradable. Based on Ames Mutagenicity tests, biodiesel provides a 90% reduction in cancer risks.
- Cetane number is significantly higher than that of conventional diesel fuel.
- Lubricity is improved over that of conventional diesel fuel.
- Has a high flash point of about 300 F compared to that of conventional diesel, which has a flash point of 125 F.

5.3 Disadvantages of biodiesel:

Some of the disadvantages of biodiesel are:

- Quality of biodiesel depends on the blend thus quality can be tampered.
- Biodiesel has excellent solvent properties. Any deposits in the filters and in the delivery systems may be dissolved by biodiesel and result in need for replacement of the filters.
- There may be problems of winter operability.
- Spills of biodiesel can decolorize any painted surface if left for long.
- Neat biodiesel demands compatible elastomers (hoses, gaskets, etc.).

Properties of biodiesels from various feedstocks are given in Table-3.

Biodiesels	**Melting Range,(Degrees Centigrade)**				
	Oil/Fat	Me. Ester	Et. Ester	Iodine No.	Cetane No.
Rapeseed oil, h.eruc.	5	0	-2	97-105	55
Rapeseed oil, I.eruc.	-5	-10	-12	110-115	58
Sunflower oil	-18	-12	-14	125-135	52
Olive oil	-12	-6	-8	77-94	60
Soyabean oil	-12	-10	-12	125-140	53
Cotton seed oil	0	-5	-8	100-115	55
Corn oil	-5	-10	-12	115-124	53
Coconut oil	20-24	-9	-6	8-10	70
Palmkernel oil	20-26	-8	-8	12-18	70
Palmoil	30-38	14	10	44-58	65
Palm oleine	20-25	5	3	85-95	65
Palm stearine	35-40	21	18	20-45	85
Tallow	35-40	16	12	50-60	75
Lard	32-36	14	10	60-70	65

Table-4: Some properties of different biodiesel fuels [3]

6. SUMMARY

The transition to these alternatives is not without challenges, including high initial costs, the need for extensive infrastructure development, and varying energy densities and performance characteristics. A multi-pronged approach combining policy incentives, technological innovation, and public-private partnerships is essential to accelerate the adoption of these alternative fuels. The future of transportation will likely involve a diverse portfolio of these energy sources, tailored to different vehicle types and regional needs, paving the way for a more sustainable and resilient global energy system. The world's reliance on fossil fuels for transportation presents significant challenges that necessitate a shift toward alternative fuels. This need is driven by three primary factors: environmental impact, energy security, and public health. The world's transportation sector is overwhelmingly dependent on fossil fuels, with over 90% of transport energy derived from oil products like gasoline and diesel. This dependency presents a variety of challenges that necessitate a transition to cleaner, more sustainable alternatives.

7. REFERENCES

1. Alternative Fuels Data Center (AFDC).
2. Website of the National Biodiesel Board, USA.
3. Biodiesel Handling & Storage Guidelines, Report of the National Renewable Energy Laboratory, NREL, USA.
4. Website:www.agricoop.nic.in.
5. Interim Report of the "Auto Fuel Policy of India".
6. Evaluation of Ethanol as Transport Fuel-Report of the Australian Greenhouse Office.
7. CPCB Sponsored Study on "Feasibility of Alternative Fuels" through IIP, Dheradun.
8. Proceedings of the recent Workshop on "Bio-fuels" by the Center for Bharatiya Marketing Development (CBMD), Delhi, 2002.
9. UNDP/UNIDO assisted Programme on "Alternate Fuels"-Report.
10. Proceedings of training on "Automobiles & Environment" organized by Japan Automotive Research Institute (JARI)-Japan, 2002.
11. "Energy Saving and Clean Energy Vehicles" by Masahiki Hori, Japan.
12. "International Conference on Sustainable Development of Alternate Energy Driven Vehicles"-Proceedings of the Conference organized by CPCB & SIAM, New Delhi, 2001.
13. "Renewable Energies-Exploring the Potential of PR China"-CTZ, China.
14. " Comparative emissions from diesel & CNG"- Millbrook.
15. "The Alternative Fuels Directory"- TNO, 1998.

-