A COMPARATIVE STUDY ON THE EXHAUST EMISSIONS FROM VARIOUS FUELS USED IN AN INTERNAL COMBUSTION ENGINE

Yadhukrishnan S[1], Anoop P[2]
[1]Department of Mechanical Engineering, M G University
BTech Student, Muthoot Institute of Science and Techonology, Puthencruz, Kerala, India
[2]Assistant Professor, Dept. of Mechanical Engineering
Muthoot Institute of Science and Techonology, Puthencruz, Kerala, India
Email: yadhuks.95@gmail.com[1], anooptherakath@gmail.com[2]

ABSTRACT

Owing to the depletion of the natural resources, nowadays gasoline has become costlier and its extensive usage makes them exhaust in upcoming years. Due to the strict environmental regulation and to minimize the carbon foot prints, a number of alternative fuels are considered instead of gasoline [1]. To determine which alternative energy source is suitable for automobiles in terms of the existing conditions is a very important issue. It is necessary to know the characteristics of these energy types and evaluate their advantages and disadvantages to make this determination. In this study, a comparative analysis is performed for fuels such as CNG, hydrogen, ethanol and methanol, which could be used as an alternative to gasoline and diesel, and electric, hybrid and fuel cell vehicles. According to the comparison, LPG and CNG are best alternative fuels for economical reasons, while electric and fuel cell vehicles stand out as their emission advantages. Also, hydrogen can be considered as a key fuel due to its usage as an energy source for both internal combustion engines and fuel cell vehicles[2]. The economics of production of alcohol fuels is higher[3] eventhough it gives moderate performance and less CO and UHC emissions[4].

KEYWORDS: CNG, Alcohol Fuels, Hydrogen, Electric Vehicles, Fuel Cell Electric Vehicles

I. INTRODUCTION

Factors such as increasing world population, economic growth and rise of per capita energy consumption, induce energy amount used in the world with each passing day. This increase in energy consumption raises two major problems; increasing energy prices due to the limitations of energy sources, and environmental pollution caused by intensive energy use[5]. The transport sector continues to account for a large share of humanity's total energy usage; the road transport sector is characterised by near-total reliance on fossil fuels. There are more than enough reasons explaining initiation of transition from the conventional options on the road transport sector toward new options including increase of oil price, the climate change problems, the increasing restrictions on pollutant emissions, the high dependence of road transport sector on oil, economic impact, and geological concerns, etc.

Global stability convincingly has never been threatened so persistently like it is by climate change and probably the threat is the most critical challenge in the way of humanity in this century[6]. To realize what was agreed by the participating governments at Cancun 2010[4], which was to limit the rise in global average temperature to less than 2°C above pre-industrial level, the total carbon dioxide volume that is allowed to be emitted until 2050 should be around 565-886 billion tonnes (Gt) [7],so that two third of this fuel must stay in the ground to meet

the goals of Cancun summit. Alternative fuels currently in use and under consideration are still carbon based. Emissions of greenhouse gases from road vehicles remain very high on the political agenda; concern over the impact of vehicles on air quality remains high. As a result of conducted researches, it is known that air pollution in major cities in the world due to motor vehicles reach 50% of total air pollution .

In internal combustion engines, not only gasoline or diesel is burned, but fuels like LPG, CNG, ethanol, methanol, biodiesel and hydrogen can be utilized as well. Regarding some engines that are called flexible fuel engines, the mixture of two or more fuels can be used. Some of the types of fuels can be used in which type of engine systems are in Table 2 below[10]. Due to global climate change fears, increasing levels of carbon dioxide in the atmosphere, and economic considerations, there is an interest in developing biological renewable alternatives for fossil fuels.

Table 2 – Types of engine, fuel, and fuel system.

Fuel	Engine	Fuel system
Gasoline	SI	Mono
Diesel	CI	Mono
LPG	SI	Mono, bi-fuel
CNG	CI, SI	Mono, bi-fuel
Hydrogen	SI, FC	Mono, bi-fuel
Ethanol	SI, CI, FC	Mono, ffv
Methanol	SI, CI, FC	Mono, ffv
Biodiesel	CI	Mono, ffv

SI: spark ignition.
CI: compression ignition.
FC: fuel cell.
mono: only one type of fuel.
bi-fuel: more than one type of fuel without mixing.
ffv: fuel blends.

II. LITERATURE SURVEY

Fuel standard specifications are applied to commercially available fuels to assure fit-for-purpose with engine performance and engine durability. Certification fuels (fuels used for engine development,calibration and certification) are typically developed to represent commercially available fuels and for "qualifying" engine/vehicle performance and emissions over representative operating scenarios[11]. The alternative energy resources are largely environment-friendly but they need to be evaluated on case-to-case basis for their advantages, disadvantages and specific applications. A variety of alternative energy sources are used in order to mobilize vehicles. CNG, ethanol, methanol, biodiesel, hydrogen, fuel cells and electricity are some of these energy sources. Various factors are outstanding for one [8,9]. Carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO) and particulate matter (PM) emissions, which are come out by motor vehicles burning hydrocarbon fuels, constitute serious health problems polluting the atmosphere. Motor vehicles are responsible not only for toxic emissions like HC, CO, NOx and PM, but also carbon dioxide (CO2) that causes the greenhouseeffect.

or more of these fuels are often used in different parts of the world. The most important factor has been the cost. In some countries however, the use of alternative fuels is encouraged as a legal obligation due to environmental reasons. Although there are some positive aspects of alternative fuels, there are also negatives. Some of them are storage challenges and costs, high initial purchase costs, the conversion costs, less availability of filling stations, longer fuel filling time and low vehicle range. Thanks to works done to overcome these negative aspects, the situation is much better than before, and it is a reality that alternative fuels will be used on a large scale over the world in the future.

Compressed natural gas (CNG)

Natural gas is a colorless, odorless gas and it is lighter than air. Methane(CH) poses the largest weight in the chemical composition of natural gas. Combustion efficiency of CH4 is very high thanks to its simple carbon structure. Vehicles powered by natural gas, are called as NGVs (Natural Gas Vehicle) briefly Vehicles may be manufactured in the factory directly to operate with natural gas. However in general, they work with a systematic called "Bi-Fuel", which requires a number of modifications to the gasoline engine, using only one fuel at a time, but having an infrastructure of two different fuels for engine working. By using natural gas as a vehicle fuel, following advantages and disadvantages are obtained [7].

Advantages:

- Natural gas sources are spread throughout the world, which reduces the risk fuel for vehicles of an energy crisis
- The consumption cost of natural gas is very low in comparison with the other fuels.
- Natural gas is one of the least polluting fuels. Exhaust emissions from the combustion of natural gas are far below the Ultra Low Emission Vehicle(ULEV) standards. Particulate emissions emitted from the CNG vehicles are better than diesel

or dual fuel engines[12]. It becomes possible to reduce NO emissions by 90% and CO emissions by 25% with the use of natural gas. Due to the low carbon content of natural gas , COx emissions decrease by up to 25%.

- Since natural gas has a high octane number, thermal efficiency of an engine powered by natural gas can be 10% higher than a gasoline engine.
- Compared with other fuels, combustion of natural gas in engines gives a 30% decrease in noise emissions.
- Thanks to its simple chemical structure, CNG establishes clean combustion in engines. Thus, vehicle engine would be less worn and a significant amount of maintenance savings achieved.
- Because CNG is lighter than air, it rises instantly in the presence of any leaks. Also due to a high ignition temperature and a wide range of flammability, the likelihood of any fire diminishes at an accident.
- CNG has the highest knock resistance. Its octane number is ca. 130. Natural gas is non-toxic, odourless and non-corrosive. It is lighter than air and is slightly soluble in water.

Disadvantages:

- CNG has lower energy content at gaseous phase. Because of this property, it is usually stored as compressed at the range of 200-250 bar pressure in vehicles. For this reason, a CNG fuel tank takes 4-5 times more volume requirements than a gasoline or diesel tank in order to carry the same amount of energy. This means again 4-5 times more weight will be on the vehicle in the case of steel used as a tank material. If composite CNG tanks are used, the problems arising from the weight (fuel consumption, range, etc.) would decrease. However, the use of such materials naturally increases the cost of these tanks.
- CNG filled into the tank at high pressure extends the filling time.

In comparison with diesel fuel, a CI engine fuelled with NG has much lower emissions of NO*x*, PM, HC and also CO [13]. Under stoichiometric and lean burn conditions CNG has lower NO*x*,CO_2 and NMHC emissions, but also a little lower brake fuel conversion efficiency. At a higher compression ratio and lean burn operation engine efficiency increases, while NO*x* and CO_2 emissions decrease. In order to reduce, Development of the CNG dual-fuel turbocharged CI engine was performed in references[14] and NG was introduced into the engine cylinder in the gaseous state through a honeycomb mixer. The pilot ignition fuel was diesel fuel. The following results were obtained:

1. In general, for dual fuelling the cylinder pressure and heat release rate are lower than for neat diesel fuelling.
2. The ignition delay is longer for dual fuelling.
3. The greater the pilot diesel fuel dose, the higher the pressure in the cylinder and the higher the rate of pressure rise.
4. An increase in pilot diesel fuel extends the lean burning limit and decreases HC and CO emissions
5. (while NO*x* emissions increase), which is generally higher than for diesel fuelling.
6. Smoke emission is considerably reduced for dual fuelling
7. NO*x* emission is also reduced
8. The brake fuel conversion efficiency is a little lower.

A CNG-fuelled engine has much lower unlimited carcinogenic emissions in comparison with a gasoline-fuelled engine

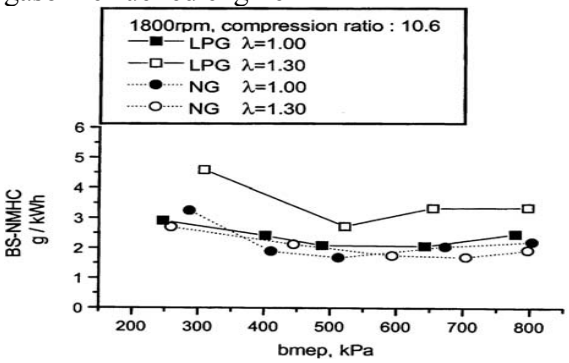


Fig 1.1 Brake specific emission of NMHC vs load [15]

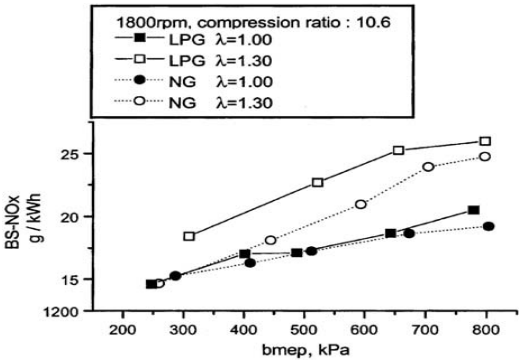


Fig 1.2 Brake specific emission of NO_x vs load[15]

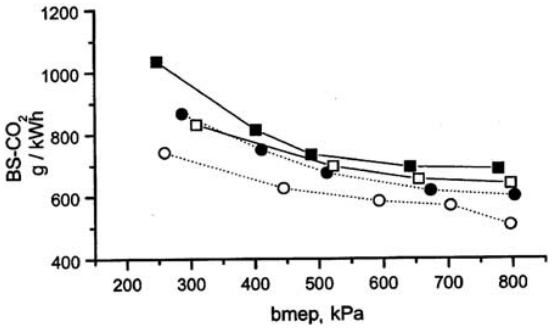


Fig 1.3 Brake specific emission of co_2 vs load[15]

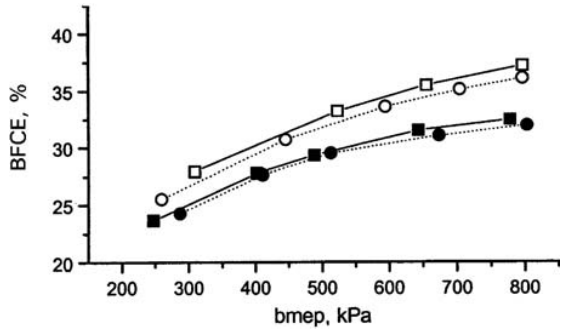


Fig 1.4 Brake fuel conversion efficiency vs load[15]

Alcohol is made from renewable resources like biomass from locally grown crops and even waste products such as waste paper, grass and tree trimmings etc. Alcohol fuels such as methanol (CH,OH),ethanol (C,H,OH) have proven to be excellent octane booster and blend with the traditional fuels, gasoline and diesel, and require minor engine modifications. Using ethanol in automobiles as a fuel several advantages and disadvantages are provided. Some of these are given below[2,21].

Advantages:

- Alcohols are the most popular additives where they have replaced all other additives as octane boosters in gasoline fuel [16]. Adding alcohols such as ethanol and methanol to gasoline allows the fuel to combust more completely due to the presence of oxygen, which increases the combustion efficiency and reduces air pollution. Besides, alcohols can be promoted as alternative fuels in ICE since they do not contain sulphur or complex organic compounds[17].
- Alcohols have higher octane number than gasoline. A fuel with a higher octane number can endure higher compression ratios before engine starts knocking, thus giving engine an ability to deliver more power efficiently and economically[18].
- Alcohol burns cleaner than regular gasoline and produce lesser carbon monoxide, HC and oxides of nitrogen[19].
- Alcohol has higher heat of vaporization; therefore, it reduces the peak temperature inside the combustion chamber leading to lower NOx emissions and increased engine power[20].
- Methanol can be made out of organic material such as biomass and municipal waste. In the long-term, it could even be made out of coal. The United States has 25% of the worlds' supply of coal, which will be abundant for years to come.
- Alcohol combustion produces higher combustion pressures inside the combustion chamber of the ICE due to the higher molar products to reactants ratio, compared to gasoline, which improves power output and thermal efficiency of gasoline.
- Increasing the compression ratio of the engine to 12: 1 or higher increases power and fuel efficiency by 20% and 15% respectively.
- Alcohols have better combustion characteristics and performance due to the increased volumetric efficiency of alcohol fuels, which is why methanol is a preferred racing fuel. Acceleration time decreases with power increase.
- Ethanol raises the knock resistance of the engine. When the ethanol amount increases in the mixture, CO, HC and CO_2 emissions are reduced .
- Through the use of methanol, CO_2 emissions, which significantly influence the greenhouse effect, decrease.

Disadvantages:

- The economics of production. Unless the cost of alcohol production from renewable resources is made cost effective, there will be no demand for it. These alcohols could be produced from biomass, coal, and natural gas.
- Flame visibility of alcohol is difficult to be detected, which might be hazardous. The lack of visibility is due to the small number of carbon atoms present in the alcohol. Since there is very little carbon, there is no soot formation to give the flame color.

- Cold storability problems. Due to their low vapor pressure, high latent heat of vaporization, and single boiling point, alcohols, especially ethanol, have difficulty meeting industry standards for starting in cold weather. The last two of these disadvantages, however, can easily be solved. By the addition of a small amount of gasoline to the alcohol mixture, a more visible flame will be produced and the effect of cold weather on engine storability can be brought well within the industry standards.
- Since alcohol does not evaporate as easily as gasoline, the intake manifold had to be redesigned to provide more heating for evaporation[22].
- Because of the low energy density of ethanol, more ethanol is needed to use than gasoline to get a distance. And this also necessitates larger and heavier fuel tanks.
- HC emissions decreases with increasing the amount of ethanol, but it increases excessively in E90 or pure ethanol use.
- Due to the certain number of ethanol is low; its self ignition resistance is very high. And that makes difficult to use ethanol in diesel engines.
- The use of methanol as an alternative fuel lasts for a short time due to its non-renewable natural resources.Because methanol has a lower energy density (1 L of gasoline equals 1,75 L of ethanol), it requires a larger and heavier fuel tank than that of gasoline for the same range.

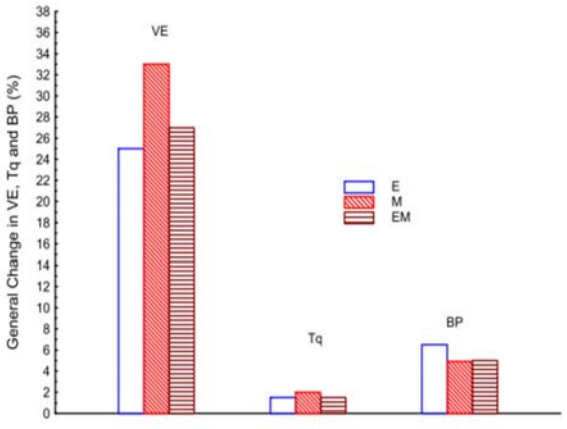


Fig. 2. General change in volumetric efficiency (VE), torque (Tq) and brake power (BP) for ethanol–gasoline blends (E), methanol–gasoline blends (M), ethanol–methanol–gasoline blends (EM) and neat gasoline (base line) in average basis.

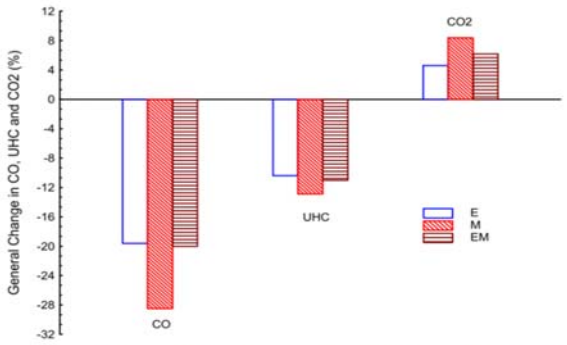


Fig. 3. General change in CO, CO_2 and UHC emissions for ethanol–gasoline blends (E), methanol–gasoline blends (M), ethanol–methanol–gasoline blends (EM) and neat gasoline (base line) in average basis.

From Fig: 2,3[2],if we aim to get less emissions of CO and UHC and higher both volumetric efficiency and output torque from SI engines we should use M fuels; however, if we interested in getting a higher output power with a bit low CO and UHC emissions, but higher than M, we should use E blends; to get a low moderate emissions of CO and UHC as well as a high moderate volumetric efficiency, torque and power, we should use EM fuels.The lowest boiling point of methanol, compared to ethanol and gasoline, is another reason for providing M with the lowest emissions (CO and UHC),followed by EM and E, respectively. One of the additional important reasons for the reductions in CO and UHC emissions and, in turn, increasing of CO_2 emissions of blended fuels are that ethanol and methanol have higher latent heat of vaporization than that of gasoline. The higher volumetric efficiency leads to more access air in the combustion chamber and, in turn, lowers CO and UHC emissions. It can be also noticed that the volumetric efficiency of M is higher than E.The higher volumetric efficiency also leads to a higher output torque from engine at using M than that E, as shown in . On the other hand, EM provided moderate volumetric efficiency and torque between M and E. Furthermore, the improved antiknock behavior (due to the addition of ethanol and methanol, which raises the octane number) allowed a more advanced timing that results in higher combustion pressure and thus much higher torque and power than those of the gasoline fuel.

Hydrogen

Hydrogen, which is the lightest element of nature, exhibits a colorless, odorless, tasteless, and a transparent structure .Hydrogen is used extensively in the space program since it has the best energyto-weight ratio of any fuel. An improved operation concerning power,

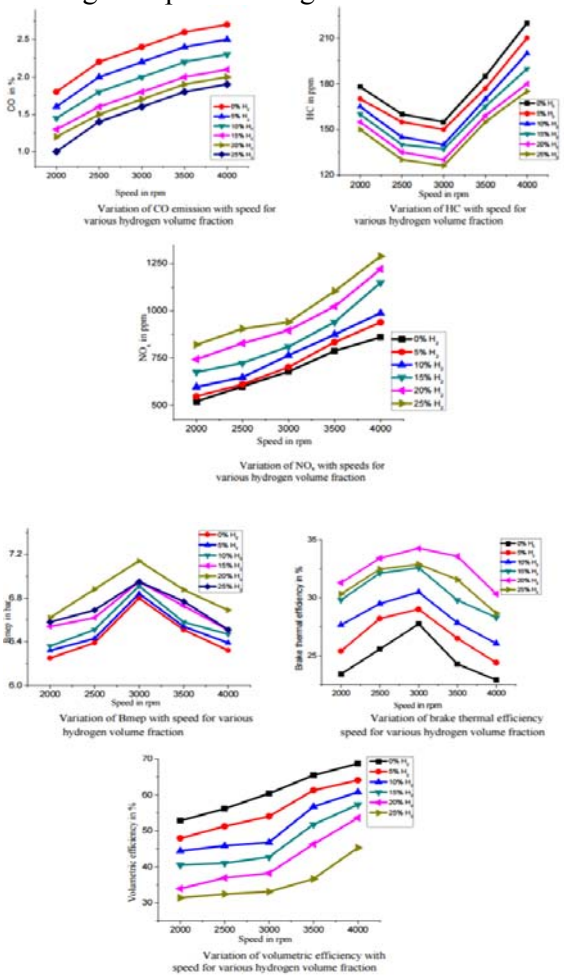
efficiency and emissions compared to conventionally fuelled engines, demands hydrogen as an alternate fuel thereby increases the mobility. The attractiveness of hydrogen lies in the variety of methods to produce hydrogen as well as the long-term viability of some of them[23]. Advantages and disadvantages of hydrogen using in automobiles are shown below[24].

Advantages:

- In hydrogen fuelled engines there are no problems such as steam stopper, condensation on cold surfaces, insufficient evaporation, and poor mixing with air seen in fossil fuel engines. Hydrogen engines present no problems at starting even at -253◌̊C
- Thermal efficiency of hydrogen-fuelled engines may be increased by 25% providing the increase of compression ratio and establishing a lean mixture.
- The amount of energy required to ignite the hydrogen-air mixture is very low compared to that of other fuels. This feature constitutes an advantage in especially gasoline engines assuring an easy ignition.
- Emissions could be significantly reduced by using different percentages of hydrogen mixed with natural gas.

Disadvantages

- Two important issues arisen from hydrogen-fuelled engines are ignition backwards and preignition events. The low ignition energy of hydrogen causes these two problems.
- NOx emissions formed by high combustion temperatures of hydrogen are higher than that of other fuels.
- Production and storage costs of hydrogen are very high.
- Hydrogen is an element, which is difficult to liquefy. It passes to liquid phase at approximately 20 K temperature and 2 bar pressure.
- Low density and low viscosity of hydrogen make it possible to seep out through very small cracks or openings of the wall of the environment.
- Hydrogen is a flammable and explosive gas. When it mixes with air at the ratio of 4-75% by volume, it may take fire easily.
- Hydrogen IC engine needs hardened valves and valve seats, stronger connecting rods, a higher voltage ignition coil, fuel injectors designed for a gas, stronger head gasket material, modified intake manifold, having high temperature engine oil.



From the graphs[24] above it can be revealed that, the BMEP rises as the hydrogen fraction increases compared to pure gasoline operation. The proper explanation for such a trend is, hydrogen has a much wider flammable range, a much faster flame propagation speed and a much higher adiabatic flame temperature than those of gasoline, which help extend the flammable range and accelerate the combustion of gasoline–hydrogen–air mixtures. But at 25% hydrogen addition fraction, BMEP drops due to improper combustion as the air content in the intake is gradually reduced with the increase of hydrogen fraction in the total intake gas. Brake thermal efficiencies of the hydrogen enriched operation are higher than those of the pure gasoline engine operation at all engine speeds. Moreover, brake thermal efficiency increases distinctively with the increase of hydrogen fraction. As the percentage of hydrogen blend increases there is a drop in volumetric efficiency due to the density

difference between the air and hydrogen. Hydrogen being lighter than air displaces the air. The volumetric efficiency is affected by the fuel being burned in the engine. Liquid fuel takes up very little space in the intake port and the combustion chamber. The hydrogen fuel vapour can take considerably more of this space, leaving less volume for the air being pumped into the cylinder. This causes less amount of mixture density at the inlet of the engine in turn reduction in volumetric efficiency.

CO level is dropped with the increase of hydrogen energy fraction due to the enhanced combustion caused by hydrogen addition and abundant oxygen available for the post-oxidation of CO emission. HC emissions decrease with the increase of hydrogen addition fraction, the shorter quenching distance of hydrogen than that of gasoline is other possible reason for the reduced HC emission. The emission of NOx is increase with the increase of hydrogen addition fraction,at very high temperature which occurs in the combustion chamber of an engine, N breaks down to monatomic N which is reactive. Other gases such as oxygen and water vapour also break down at high temperatures leading to the formation of NOx.

Electric vehicles (EV)

The movement of the vehicle is provided by electric motors in electric vehicles similar to the fuel cell systems. The electricity, which is transferred from an external source, is stored in batteries (BEVs) or by a fuel cell system(FCEVs). Both BEV and FCEV are often regarded as the only long term complete solution to the problem of pollution in urban areas, as well as to the problem of CO_2 emissions. Fuel cells, which convert fuel energy into electrical energy with electrochemical principle, are efficient, quiet, environmentally compatible power generation element. Advantages and disadvantages of fuel cell and battery storage systems are as follows[2].

Advantages:

- Energy consumption costs of electric vehicles are very low. These costs vary depending on the price of electricity of the country.
- Due to the absence of lots of moving parts, repair and maintenance costs are low.
- They run without noise and vibration.
- Well to wheel efficiency of electric vehicles rises up to 40%, while it is about 15% in internal combustion engines.
- EVs have the ability to produce higher torque.
- No emissions emitted to the atmosphere during the operation of the car.
- Electricity can be obtained by renewable methods (biomass, wind, hydro, sun, etc.).
- Thanks to the electric motors are attached directly to the wheels, there is no need for some parts such as gearbox, differential, and so forth.
- The performance of fuel cells does not decrease as time goes, and recharging of the system is not needed.

Disadvantages:

- The biggest drawback of EVs is the storage problem of electricity in batteries. That is because the range of EVs is very low.
- Charge duration of battery in EVs is very long compared to that of fossil fuel vehicles.
- Because batteries of EVs are recharged from the mains, the environmental impact of the electricity produced varies from country to country.
- The initial purchase cost of EVs is high.
- Charging stations of EVs are not common.
- Silent operation of EVs poses a hazard to pedestrians.
- Fuel cell systems are very expensive according to internal combustion engines. Studies continue to reduce costs reducing the amount of platinum used mainly.
- There is a difficulty providing hydrogen that is required for the operation of fuel cells.

when using 100% renewable energy sources to generate electricity, the BEV is the most efficient option, obviously also featuring zero emissions; when using an average primary source mix in electricity generation, or a 100% coal or natural gas feeding, the BEV performances are much lower, and the FCEV solutions become much more favourable both by the point of view of efficiency and CO emissions

III. DISCUSSION

A general comparison of alternative energy sources used in automobiles is given in Table 3. The presented table provides an overall summary of the study. Some of the important options of alternative energy sources are evaluated with respect to the conventional fuels (gasoline and diesel). The rankings are based on the cited

literature in this work. The criteria of the comparison of the alternative energy sources are grouped under three main headings. Costs, section, emissions part, the other part includes features such as range, performance, fuel station availability. Ratings of the alternative energy sources for the criterions are given in four signs; - -,-,+,++ regarding very low, low, high, very high, respectively.

	Gasoline	diesel	CNG	ethanol	methanol	hydrogen	FCEVs	EVs
Cost								
Vehicle	++	+	+	++	++	+	--	-
Fuel consumption	-	+	++	-	-	--	--	++
Maintainence	+	-	+	+	+	+	--	--
Emissions								
HC	--	-	-	-	--	++	++	++
CO	--	+	+	-	-	++	++	++
NOx	-	--	+	+	+	--	++	++
CO2	--	-	+	-	-	++	++	++
Other								
Range	+	++	-	+	-	--	--	--
Performance	++	++	+	+	+	-	--	--
Fuel station availability	++	++	-	+	-	-	--	--

Table 3

In terms of the costs, CNG is the most advantages energy sources due to their first purchase costs of the vehicle, fuel consumption costs, and repair-maintenance costs compared to that of the others. In this section, FCVs are the worst option with very high costs, however. Regarding the emissions part, FCVs and EVs come to the fore with their environmental friendly electric motors. Hydrogen follows FCVs and EVS in emissions section with its NO drawbacks. Gasoline and diesel engines are the most negative choices regarding the other energy sources in terms of the emissions. Alcohol fuel blends are acceptable but their production from renewable sources are not cost effective.

IV. CONCLUSION

Various alternative fuels are candidates for partial or total replacement of fossil fuel for spark ignition (SI) engines used in the transport sector. The use of alternative energy sources in automobiles is gaining importance with each passing year due to the rapidly depletion of available energy resources, the rise in fuel prices depending on this depletion, and environmental factors. The most important factors in the acceptance of alternative energy sources are the initial purchase cost of the system, the cheapness of the fuel, station availability and filling duration of the fuel, vehicle range and performance, and the environmental impact. Of all the alternate fuels listed here CNG seemed to be best alternative fuels for economic reasons, while electric and fuel cell electric vehicles(FCEVs) for their emissive advantage. Hydrogen is considered as a key fuel due to its usage as a energy source for IC engines and FCEVs. CNG had undeniable advantages in terms of exhaust CO_2 emissions; for ethanol blends the environmental performance depends fully on the origin of the ethanol and the sustainability and energy intensity of its production process.

V. FUTUREWORK

From the above discussion, the use of hydrogen or CNG as a fuel in urban vehicles is advantageous. Both of them can be used as mono or bi- fuels with gasoline blends. CNG is having a greater chance to be used as mono fuel. But to enhance the properties of CNG as a fuel we can also use hydrogen combined CNG(HCNG). One of the primarily concern is about hydrogen production and storage. Thus we are looking forward in using CNG, HCNG and hydrogen gasoline blends in SI engines. Also with production of hydrogen within the vehicle itself by use of electrolysis process.

VI. REFERENCES

[1] J. Akash Nirmal Kumar, N. Gowtham and S. Senthil, International Review of Applied Engineering and Research. *Design and Fabrication of Hydrogen Powered IC Engine* ISSN 2248-9967 Volume 4, Number 5 (2014), pp. 423-426.

[2]Adem Ugurlu, Semiha Oztuna, *A comparative analysis study of alternative energy sources for automobiles*, international journal of hydrogen energy xxx (2015). pp. 1-11

[3]Mayank Chandra Joshi, Mayank Joshi, Sumit Suyal, Anurag Bahuguna, *Alcohol as an Alternative Fuel in I.C. Engine: A Review*, International Journal of Engineering and Technical Research (IJETR) ISSN: 2321-0869 (O) 2454-4698 (P), Volume-4, Issue-2, February 2016

[4]Ashraf Elfasakhany, Full length *article Investigations on the effects of ethanolemethanolegasoline blends in a spark-ignition engine: Performance and emissions*

analysis, Engineering Science and Technology, an International Journal 18 (2015). pp. 713-719

[5] Donmez R, Gu¨du¨T. Tas,itlarda LPG Kullanimi ve Sonuc¸ lari.Ankara: 3.LPG-CNG Kongresi ve Sergisi Bildiriler Kitabi; 2007.p. 153-9.

[6].University of Oxford.*Global Challenges – Twelve risks that threaten human civilisation*, Future of Humanity Institute, Oxford Martin School & Faculty of Philosophy; 2015.

[7]. Meinshausen M, Meinshausen N, Hare W, Raper SC, Frieler K, Knutti R, Frame DJ, Allen MR. Greenhouse-gas emission targets for limiting global warming to 2 C. *Nature* 2009; 458: 1158-1162.

[8]Sharma.P,Khara. M. Modeling of vehicular exhaust- a review.Transp Res 2001:179-98.

[9] S,ahin A, Sen Z. Future prospects of fossil and alternative energy sources. In: Proceedings of the first international energy and environment symposium; 1996. p. 37-43.

[10]Tekiner. K. Dogalgazin Sikis, tirilmis,Formlarinin.Arac¸ lardamotor Yakiti Olarak Kullanilmasive Uygulama S,artlarinin_Incelenmesi. Yildiz Teknik U¨niversitesi, Fen BilimleriEnstitusu,Yuksek Lisans Tezi; 2006

[11]Fanick,"Novel Renewable Additive for Diesel Engines". SAE 2014-01-1262

[12] Ulusoy BS. Alternatif Yakitlarin Benzinli motor Emisyonlari Uzerine Etkisinin_Incelenmesi.Kirikkale Universitesi Fen Bilimleri Enstitus,Yuksek Lisans Tezi; 2005.

[13] Kim,C.U.and Bae, C. S. Speciated hydrocarbon emission from a gas fuelled spark ignition engine with various operating parameters.*Proc.Instn Mech.Engrs, Part D: J. Automobile Engineering*, 2000,214(D7), 795–808.

[14] Shengua, L., Wang, Z. and Jiang, R. Development of compressed natural gas/diesel dual-fuel turbo charged compression ignition engine. *Proc. Instn Mech. Engrs, Part D: J. Automobile Engineering*, 2003, 217(D9), 839–845.

[15] Kim,C.U.and Bae, C. S. Speciated hydrocarbon emission from a gas fuelled spark ignition engine with various operating parameters. *Proc. Instn Mech Engrs, Part D: J. Automobile Engineering*, 2000, 214(D7), 795–808.

[16] V.R. Surisetty, A.K. Dalai, J. Kozinski, Alcohols as alternative fuels: an overview, Appl. Catal. A: General 404 (2011) 1-11.

[17] A. Elfasakhany, Investigation on performance and emissions characteristics of an internal combustion engine fuelled with petroleum gasoline and a hybrid methanol-gasoline fuel, IJET-IJENS 13 (2013) 24-43.

[18] Kim S, Dale BE. Environmental aspects of ethanol derived from no-tilled corn grain: nonrenewable energy consumption and greenhouse gas. Biomass Bioenergy 2005; 28:475–89.

[19] DA, Caffrey PJ, Rao V. Investigation into the vehicular exhaust emission of high percentage Ethanol blends. SAE paper no. 950777.

[20] Taylor AB, Mocan DP, Bell AJ, Hodgson NG, Myburgh IS, Botha JJ. Gasoline/alcohol blends: exhaust emission, performance and Burn-rate in multi-valve production engine, SAE paper no. 961988, 1996.

[21] Mayank Chandra Joshi, Mayank Joshi, Sumit Suyal, Anurag Bahuguna. Alcohol as an Alternative Fuel in I.C. Engine: A Review International Journal of Engineering and Technical Research (IJETR) ISSN: 2321-0869 (O) 2454-4698 (P), Volume-4, Issue-2, February 2016, pp 87-92

[22] Avinash Kumar Agarwal. Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines. Progress in Energy and Combustion Science 33 (2007) 233–271

[23] Mazloomi, K., & Gomes, C. (2012). Hydrogen as an energy carrier: prospects and challenges. *Renewable and Sustainable Energy Reviews*, *16*,5, pp..3024- 3033

[24] Shivaprasad K V, Raviteja S, Parashuram Chitragar, Kumar G N. Experimental Investigation of the Effect of Hydrogen Addition on Combustion Performance and Emissions Characteristics of a Spark Ignition High Speed Gasoline Engine . 2nd International Conference on Innovations in Automation and Mechatronics Engineering, ICIAME 2014, Procedia Technology 14 (2014) 141 – 148