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Alternative Energy Technologies: The Unconventional Dependable

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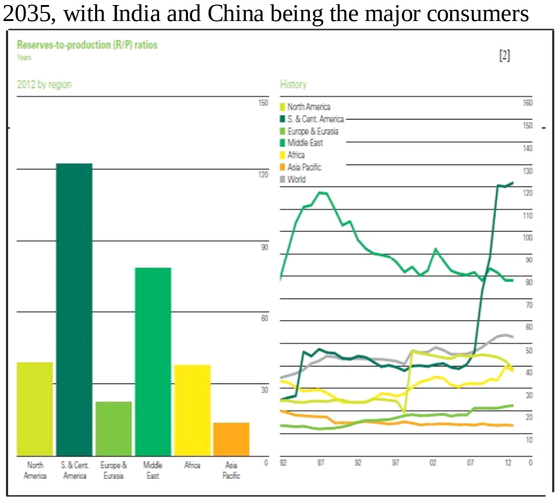
Abstract

AETs are imperative to mitigate the twin crisis of environmental degradation and simultaneous fossil fuel depletion, there are wide concerns about GHG emissions which have paved ways for the development and deployment of energy technologies that do not use fossil fuels. These technologies would provide tangible benefits in terms of fossil-fuel costs, which are likely to increase as restrictions on GHG emissions are imposed. However, a number of challenges need to be overcome prior to market positioning, and the commercialization of alternative energy technologies which require a staged approach given price and technical risk. An unconventional new alternative technology is one possibility, where one could undertake cost- reducing production enhancement measures as an intermediate step prior to deployment. This paper explores the factors affecting the use of AETs in automobiles further includes in depth analysis and results obtained from real time experiments conducted on AET based automobiles. This paper empirically examines the preferences for alternative energy sources or propulsion technologies in vehicles. In order to simulate a realistic future purchase situation, the following alternative technologies i.e. hybrid, gas, biofuel, hydrogen, and electric vehicles were considered besides common gasoline and diesel vehicles. There is a need for common policy instruments such as the promotion of research and development, taxation, or subsidization in the field of electro mobility could be supplemented by policies to increase the social acceptance of alternative vehicle types.

1. Introduction

The increased use of automobiles with the swift speed of industrial growth in the world made petroleum supplies unable to keep up with the demands. Moreover, petroleum fuels pollute the environment with their combustion products.

Use of control devices led to reduction in pollution buy also a 15% reduction in the vehicle mileage [1].World proved oil reserves by the end of 2012 were 1668.9 billion barrels, sufficient to meet 52.9 years of global production. OPEC member countries continue to dominate holding 72.6 % of the total [2].Though the consumption is set to rise by 2035, with India and China being the major consumers



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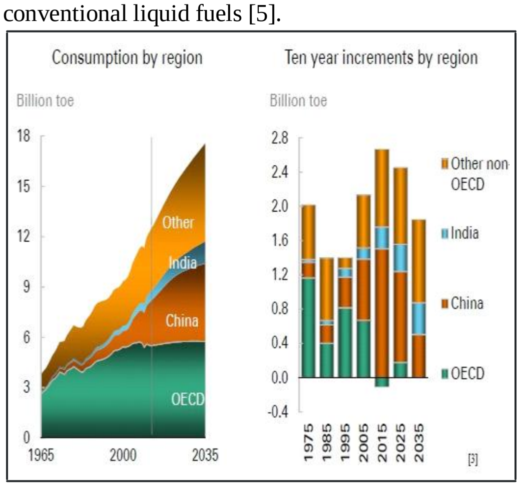
[3]. Tighter government, state and local emissions regulations have led to a search for alternative fuels.

Liquid petroleum gas and alcohol are currently in use in autom- obiles . Many considerations determine the viability of an alter- native fuel, including emissions, cost, fuel availability, fuel con- sumption, safety, engine life, fueling facilities, weight and space requirements of fuel tanks, and the range of a fully fueled vehic- le. Currently, the major competing alternative fuels include eth- anol, methanol, propane, and natural gas [4].

Two categories of fuels are investigated: alcohol fuels and gaseous fuels. Alcohols could be produced from renewable resources and produce less exhaust pollutants. Gaseous fuels offer, cleaner combustion due to improved A/F mixture preparation and higher H/C ratio than in conventional liquid fuels [5].



This paper examines the effect of different alternative fuels on engine performance which was studied using a FORTRAN program(with the help of KIVA) and MATLAB Engine. The predicted results were compared with actual engine performance at the same operating conditions. Apart from this, the existing barriers for the implementation and existing policy measures to overcome the former. An analytical framework of political, socio-economic and technological environments affecting energy use in the transport system is presented. Firstly there is discussion on alternative fuels followed by the engine analysis, post which all the advantages are summarized. The new technologies play an essential role as its proper implementation can itself lead to a significant reduction in the consumption percentage.

Fuels

Engines fueled with gaseous fuels have certain advantages over gasoline-fueled engines, such as:

a- Eliminating most of the starting difficulties associated with gasoline.
b- Less scale and gum build-up inside the combustion chamber, thus requiring less frequent engine overhaul.
c- Reduced evaporative emission from carburetor and fuel
2. Tank, whereas with gasoline it is a major factor that affects air pollution.
d- Proper distribution of A/F mixture over the cylinders, thereby reducing the cyclic variation problem.
e- Less pollutants with less corrosive elements improves the service life of the exhaust system.
f- Reduced contamination of lubricating oil, thereby extending periods between oil and filter changes.

The main gaseous fuels considered in this work are: natural gas, hydrogen and synthetic fuels. Gases could be obtained from chemical industry with low thermal value of 0.54 kWh/N-m3; gases with low methane numbers (e.g. high H2 content) and hence low knock resistance; and gases with very high thermal value upto 34 kWh/Nm3 (butane) [6].

1. Natural Gas (NG)

It comprises mainly of 95% methane, 3% ethane with minor percentage of propane and butane.

Natural gas is used as an automotive fuel either compressed in cylinders CNG or liquefied LNG. In practice LNG is rarely used as it is more expensive and difficult to handle. Due to its high octane number O.N.(120+ [4]), higher compression ratio could be used to benefit from the 33% higher combustion rate, hence NG is an excellent fuel for spark ignition engines [7].

It has 99% less CO and 85% less reactive HC emissions than gasoline, with no particulates and almost no sulfur dioxide. Some advantages [4] include:

a- The fuel costs less.
b- It's the cleanest alternative HC fuel.
c- It's lighter than air so it dissipates quickly. d-It has higher ignition temperature.
e- The fuel tanks on NGVs are safer than those on gas-oline-fueled vehicles. The fuel tanks used for CNG are aluminium or steel cylinders with walls that are ½ to ¾ inch (13 to 19 mm) thick which can withstand direct g -unfire, dynamite explosions, and burning beyond any standard sheet metal gasoline tank.
f- It reduces vehicle maintenance as it burns cleanly. However, refueling systems require a compressor which increases the cost to $1900-$3900 per vehicle [1].

The relative disadvantages associated with using the NG are the reduction in the engine volumetric efficiency. Moreover, NG must be stored in a high pressure tank which is heavy and reduces the payload and luggage space. An NG car with 75 litre tank is about 150 kg heavier than its gasoline counterpart [8]. Small changes in the concentration of butane produce linear significant changes in both the values of knock limited compression ratio for fixed spark timing and the knock limited spark timing for a fixed compression ratio [9].

The use of syngas with NG extends the exhaust gas recirculation (EGR) tolerance by 45% on mass basis compared to NG only, leading to 77% reduction in NOX over NG with EGR [10].

Lack of range is because CNG has about 33,000 to 38,000 Btu at 3,000 psi. CNG cylinders take up boot space and weighs about 300 pounds (136 kilograms) which is disadvantageous [4].

Considering thermal stability and heat transfer, it was found that the use of high-purity methane instead of N.G. at temperature, above 775 K, could reduce the deposit thickness by as much as a factor of three, or permit operation at correspondingly higher temperatures [11].

2.1 Barriers to implementation

Financial barriers are a problem to deployment, especially in those countries which are at the very start in terms of infrastructure development. The capital cost of the gas powered vehicles tends to be higher than the alternatives, and prospective users of gas powered vehicles will only use such vehicles if the overall lifetime cost is less than the alternatives. This additional cost of the vehicle compared to a conventional would be eliminated if vehicles were mass-produced. However, in the current market, the development of a gas powered engine from a new fundamental concept is risky, as there is no guarantee for sufficient demand at the end of the development phase. Likewise, the cost of implementing a widespread infrastructure of filling stations would be significant, and would need to be reflected in the price of the gas supplied. Companies are reluctant to invest on a large scale unless they are forced to, either by government legislation or by consumer pressures. Depending on different countries, this means: subsidies for domestic programmes, gas utilities being responsible for refueling stations and providing competitive gas prices, vehicle makers providing facilities for purchasing gas vehicles.

The lack of specific legislation and safety certification serves as a major barrier to the introduction of gas .The tax applicable to gas used as a fuel in transport is a decisive factor in deciding on the financial viability of this technology. Incentives of a fiscal nature should be based on the environmental enhancement brought about by gas compared with the use of other fuels. The European Commission has proposed that the tax applicable to alternative energies should not exceed 10% of the amount of the tax applicable to fossil fuels. Given the loss of income that this would involve, governments have treated this proposal with caution [12].

3. Liquefied Petroleum Gas (Lpg)

LPG is a by-product of crude oil refining, and it is also found in natural gas wells. LP gas is mostly propane with a small percentage of butane (upto 8 percent) .LP gas is a vapor above -40 degree F .It has a lower heat energy per volume than gasoline(about 84,000 btu),it does have a higher octane rating of 104 which allows its use in engines with higher compression ratios[4].The potential for LPG use is limited due to its availability LPG in refineries (only 5% of crude oil input [13]). Pilot demonstration projects are being implemented in several cities throughout Europe. Leading LPG engine companies are continuously carrying out R&D activities concerning LPG engines. LPG engines have developed alongside petrol engines on which they are based.

In future years there will be a technological potential for developing new LPG injection equipment which will make the use of LPG more attractive.

Since LPG is heavier than air [14], its use is subjected to certain restrictions in various countries. Workshops must be adapted for these vehicles and equipped with a fireproof electrical system, drainage U-traps and special gas detectors and ventilation systems, all adapted to the number of vehicles used by the workshop. The right safety installations should be made compulsory in vehicles and refilling stations. The indoor parking should be adapted with specific ventilation. LP gas burns clean in engine because it vaporizes at atmospheric temperatures and pressures. Since it vaporizes so readily, it does not puddle in the intake manifold, which means it emits fewer HC and less CO without added emission control devices [4].

3.1 Barriers to implementation

Financial barriers are quite similar to those for the deployment of natural gas engines. The LPG car is still a gasoline car retrofitted for LPG. This creates a supplementary cost. However, this should not be a fundamental barrier considering the life- time of the car and the fact that the LPG system can be taken from one car to the next one. Due to the extra cost of LPG equi- pment there is a need for an adequate financial regime for ro- ad taxation and for excise duty. Otherwise the turning point f- or the decision to use LPG will be too high.

The supplementary tax for LPG cars compensates the advantage coming from the price of LPG itself for cars running less than about 15,000 km/year, when compared to a gasoline car [15].

The supply and distribution systems that are required for this alternative fuel could provide a significant barrier to its deployment. However, this barrier is tempered by the fact that the existing players in the market — notably the major oil companies — would also be significant players in the LPG market (as it has similar origins to more traditional fuels). An LPG station is hardly different from a petrol station.

The actual distribution network could not cope with a mass increase of LPG vehicles. The rise of the market must be progressive in order to avoid bottlenecks, but strong enough to give the signal of needed investment to distribution companies.

It is unlikely that gas powered vehicles will take a significant proportion of the private vehicle market, due to the low number of public gas filling stations. However, the market for fleet vehicles, especially those based in urban areas with a regular base is likely to be a suitable target, since vehicle autonomy is limited. The vehicles that are most likely to be converted to gas power (buses and urban delivery vehicles) tend to have a relatively long service life. Therefore long-term uncertainty over gas prices and supply is likely to discourage the use of the technology. Additionally, the long vehicle life means that even if all vehicles due for replacement were replaced with gas powered vehicles, it would take a significant time before the fleet became 100% gas powered.

It is unlikely that LPG vehicles will take a significant proportion of the private vehicle market, due to both the low number of public gas filling stations and the overall restraint on LPG obtainability in the longer term. However, the market for fleet vehicles, especially those based in urban areas with a regular base, is likely to be a suitable target.

The fact that a car buyer must first choose between gasoline and diesel and then decide to install LPG (and pay a supplement for installation and for tax) is a clear barrier for private vehicles [15].

4. Hydrogen (H2) Fuel

Hydrogen (H2) is a highly promising fuel. It's highly flammable and has an energy content of 113,000 to 134,000 Btu per gallon and an octane rating of 130.It is blended with CNG with a ratio of 1/4 (H2 : CNG) which results in lower emissions even lesser than ones fueled solely by CNG.. Hydrogen-fueled engines are 60% efficient [4].

To reduce dependence on 'foreign' fuel sources, countries search economical and efficient ways to derive hydrogen from their domestic new clean resources [16]. Hydrogen can be produced from a variety of sources, such as biomass, natural gas, water, waste, solar photovoltaic, etc. 'Green' resources can be used to produce electricity from which hydrogen can be obtained through the electrolysis process. In transport, this process occurs in fuel cell engines.

Costs are falling, even more with initiatives such as the integration of hydrogen systems for stationary power supply [17]. Although the fuel cell technique has been known for more than 150 years now, the application to transport is still in a developing stage. Fuel cells are usually classified by their electrolyte. Of all the fuel cell types it is Polymer Electrolyte Membrane Fuel Cell technique which has the largest potential for cost reduction. So far test applications in cars proved good acceleration performance up to 90 km/h and a maximum speed of 110 km/h. The range is 250 km. As a long-term option, possibilities for cost reduction are considered in the reduction of catalysts load, reduction of CO sensitivity, simpler systems, which do not require pressurized operation. System development also has to consider environmental issues, such as performance during vibration, or operation and parking at outdoor temperatures between —30 °C and +40 °C [17]. Another big research field is the development of direct Methanol Fuel Cells. This concept uses methanol as a fuel and does not need a pre-reformer. The stacks can be cheaply mass- produced and the use of methanol assures simple storage and distribution of the fuel. Major technical problems still exist. The necessary research and development will postpone a possible introduction for a longer period than for the other fuel cell types.

Main types of fuel cells and their applications

Fuel cell	Applications [15]
Solid oxide fuel cell	Combined heat and power, power generation
Polymer electrolyte membrane fuel cell or solid polymer fuel cell	Transport, combined heat and power, distributed power generation
Alkaline fuel cell	Space, transport
Molten carbonate fuel cell	Power generation, combined heat and power
Phosphoric acid fuel cell	Combined heat and power, power generation

The transition to bulk market hydrogen vehicles will only be possible with a fully developed hydrogen infrastructure. This is a commonly acknowledged hindrance and therefore hydrogen taken from natural gas seems likely to provide a step on the route to an acceptable transition to hydrogen vehicles. But the practical feasibility of this option will also depend on factors other than environmental ones. Indeed, since greenhouse gas emissions of fuel cell vehicles using hydrogen from gas are broadly similar to those of diesel hybrids, the "cost" element will play a crucial role against fuel cells and strongly in favour of high-tech hybrids, at a fraction of the cost of fuel cell already today.

Barriers to implementation

There are five main issues that are critical for the introduction of hydrogen in transport [18]:

1. The performance of fuel cell or hydrogen-based vehicles can potentially match with that of conventional technologies. Fuel cells even offer some advantages in auxiliary power units and some niche markets. But everything else being equal, hydrogen-based technologies do not still offer enough advantages to shift user choices. It is obvious that in order to be competitive, they have to provide comparable performance at comparable cost, with accessible and reliable infrastructure. Otherwise, only a strong shift in user choices towards clean technologies would justify the substitution of the proven conventional technologies.
2. The cost of fuel cell vehicles and the cost of hydrogen as a fuel are expected to continue to fall in the future as a result of the constant improvement of technologies. A crucial condition for the reduction of costs is the realization of economies of scale in both vehicle and fuel productions. The relative cost of hydrogen compared to conventional or other fuels is the main factor from the economic point of view. The boundary conditions for which hydrogen would have an advantage correspond to the case of high oil prices combined with either low natural gas prices or low electricity prices.
3. The commitment of the industry could be influenced by policy. The key industrial stakeholders (car manufacturers, refineries and fuel providers, infrastructure providers, and fleet managers) will invest in a new technology only if the future market prospects are clear. The role of policymakers should therefore be that of decreasing uncertainty through suitable and timely policy measures, legislation and standards. Legislation could also influence user choices, by promoting the use of hydrogen, penalizing CO2 emissions, or by limiting the use of conventional technologies in certain areas.
4. Distribution and storage raise important challenges. The development of a wide network of refueling stations is a major prerequisite, but would need a critical mass of demand before it takes off. In this context, it is indispensable that the cost of hydrogen distribution is kept low and that its introduction is massive, so that the investment costs are justified. Economically, this challenge is not as big as it might appear. In the EU, approximately 100,000 refueling stations supply fuels to road transport. About 20% of these should be equipped with hydrogen dispensers before fuel cell vehicles are brought to the mass market. Assuming investment costs of 1.3 million Euros per station a basic refueling infrastructure sums up to 26 billion Euros.
5. Significant environmental benefits may occur, depending on the primary energy used for hydrogen production. Electrolysis-based solutions would only be beneficial for the environment as long as the electricity used for the electrolysis is produced from carbon-free fuels. Solutions based on reformation of fossil fuels would be neutral from the environmental point of view. The introduction of hydrogen in transport would therefore be feasible only in the case of low-cost renewables in electricity generation or in the case of high-performance fuel cells with low prices of natural gas or biofuels. Only stringent environmental legislation world-wide would increase the options for fuel cells, local restrictions will not open the market.

The year 2020 seems to be too early for a wide scale introduction of hydrogen or fuel cells; it is uncertain whether even year 2030 is a feasible time horizon. But it is also clear that even if the goal is the shift to hydrogen after year 2030, the preparation needs to start already.

5. Methanol and Ethanol Fuel

Methanol and ethanol have a number of similar properties and hence require similar attention while considering fueling, combustion, storage and handling [19]. Alcohols have high oxygen content hence lower stoichiometric A/F ratio. Consequently engine displacement volume (Vd) could be reduced. However, alcohols have approximately half the internal energy of combustion (Urp) of that of gasoline. Thereby to obtain the same power output from the engine, the flow rate of alcohol needs to be doubled and consequently the relevant air, thus keeping Vd unaltered, but increasing the capacity of carburetor jets, injectors, fuel pumps and tanks. Methanol has a latent heat of vaporization hfg about four times that of gasoline. This coupled to the fact that twice the fuel quantity to be used, means that the heat required for vaporization is about eight times greater for methanol. In SI engine this heat must be supplied in the inlet manifold prior to entry into engine cylinders, to avoid sever wear problems within the engine. However, correct vaporization results in decrease of inlet air temperature resulting in improved volumetric efficiency and greater torque and power. Reduction in vehicles' gear ratios should be made to take advantage of the increase in torque, if fuel economy is to be improved. High hfg and oxygen content may contribute to poor drivability. The relatively high fixed boiling point of alcohols results in low vapour pressure not sufficient to start the engine, resulting in poor cold starting performance. This can be overcome with the use of heaters, more volatile fuel additive or employing a secondary "cold start" fuel. Being a polar fluid, methanol may be incompatible with many metals and elastomers [20]. It is more corrosive than ethanol. Metals affected, such as Mg, Al, Zn and Cu should be replaced or plated with nickel for protection. The exposure of plastic and rubber components- in the fuel delivery system – to alcohol can cause swelling and softening. Hence, proper material selection is essential. Other engine and vehicle modifications include: spark plugs with higher heat rating; suitable engine oil; corrosion resistant and increased capacity fuel tank and lines; and modified bearings. Taking advantage of the higher octane rating, the compression ratio can be increased to 12 without encountering spark knock, which results in higher thermal efficiency and power output for the same energy input as petrol. This coupled with the ability to burn lean mixtures with improved volumetric efficiency and soot free combustion means that alcohols are viable alternative to gasoline in spark ignition engines [19].The addition of ethanol (10%) to gasoline in S. I. E. with a typical 3-way catalyst increases both Research Octane Number (RON) and the Reid vapour pressure but increases emissions of acetaldehyde and ethanol; whereas addition of methyl tertiary butyl ether (MTBE) causes only an increase in RON with less unburned HC, CO and acetaldehyde [20].The addition of ethanol to diesel in compression ignition engine results in CO reduction due to presence of more oxygen in the combustion process. However, the power decreases with the increase of ethanol [1].

E85 is a mixture of 85% ethanol and 15% unleaded gasoline.E85 has a per-gallon Btu rating of about 80,000 and octane rating of 100 [4].

6. Synthetic Fuel

Gasification processes have been developed which can produce synthetic fuel with approximate formula $(CH_2O)_n$. A typical volumetric analysis of the fuel is: 0.3% CH_4, 29.6% H_2, 41% CO, 10% CO_2, 17% H_2O and 0.8% N_2. Hence, CH_4 and N_2 can be neglected, H_2O can be removed by using vapour trap and CO_2 extracted for other uses. This results in a fuel which consists of CO and H_2. Advanced gasifiers are being developed which produce H_2 and CO in roughly equal amounts [22].

Although synthetic A/F mixtures have slower burning than gasoline-air mixtures, the first should be used with low compression ratio rc engine to avoid knock. However, it was found that with synthetic fuels the engine rc can be increased to 14 instead of 8 the typical value for gasoline [20]. This is thought to be due to the relatively lower heating value, hence lower heat release per unit mixture with consequent reduced temperature and lower tendency to knock.

Biodiesel is being recently developed to be used as a fuel in compression ignition engines CIE [23, 24]. The combustion related properties of vegetable oils are somewhat similar to diesel oil. Neat vegetable oils or their blends with diesel, however pose various long-term problems in C.I.E. e.g.: poor atomization characteristics, ring sticking, injector coking, injector deposits, injector pump failure and lube oil dilution by crank-case polymerization. These undesirable features of vegetable oils are due to their inherent properties like high viscosity, low volatility and polyunsaturated character [23]. Using 20% biodiesel-fuelled engine, the physical wear of various vital parts, injector coking, carbon deposits on piston and ring sticking were found to be substantially lower. The lube oil analysis showed lower wear and thus improved life for biodiesel operated engines [23, 24].

Fuel Performance in Internal Combustion Engines

It is imperative to explore the fuel performance relative to different engine designs which covers a range of parameters that are fundamental to basic vehicle operation and related to engine performance. These parameters and their link to key fuel properties are discussed below [25]:

a- Power output is related to A/F, internal energy of combustion Urp, and maximum flame temperature: Fuel consumption depends on engine thermal efficiency, power and F/A besides Urp.

b- Wear life of fuel pump, fuel system and injectors is related to lubricant and particulate content. High – temperature corrosion of combustion chamber, igniter and injectors are related to vanadium, Ni, K, S and Na contents. Ceramics are less sensitive to these contaminants.

c- Materials compatibility is associated with the ability of fuel-wetted metallic and elastomeric materials to withstand corrosion and dimensional instability. Key fuel properties are sulfur content, acidity and aromatic content.

d- Initiation of combustion is related to spontaneous ignition temperature Tsp, vapour pressure, viscosity, volatility, stoichiometric A/F and flame speed [26] combustion stability is affected by laminar flame speed SL, flammability limits, viscosity and Tsp.

e- Safety in fuel tank and engine, to avoid fire when the engine is shut down, is affected by flammability limits, vapour pressure, flash point, Tsp and electrical conductivity. f-Fuel handling and delivery to the injection point into the engine is related to fuel properties such as viscosity, cloud point, pour point and vapour pressure.

f- Reliability and durability is affected by ash and particulates, gum content, metals content, lubricity, fuel stability and carbon residue.

g- Low-temperature corrosion due to contact with cool exhaust gases is related to sulfur content. Exhaust emissions are affected by the percent content of aromatics, carbon, sulfur, particulate, nitrogen, hydrogen, oxygen and ash.

7. Analysis of Results

A computer program based on FORTRAN and MATLAB Engine using C_8H_{18} as a fuel [19], was used then further modified to compare the performance of spark ignition engine S.I., using gasoline taking into consideration the four following modifications on the fuel air cycle, namely: progressive combustion, valve timing, heat transfer

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and friction [19]. The operating variables namely rc, SA and rpm were varied as shown in Table 1 with gasoline, whereas the corresponding experimental results are shown in Table 2. The experimental device was a single cylinder variable compression engine with

B= 0.085m, S=0.092m, L=0.145m, AO= 7.045mm2 IVO=39°ABDC, EVO=39°BBDC, VDISP=0.58234 X 10-3 m3

The average operating conditions were assumed PM=P1=101.4 k Pa

Tg=1500 K Tw=400 K

R=8.314 kJ/ kmol-K

Table: 1. Operating Variables with Gasoline D.P

C.R.	6.00	7.00	8.00	10.00
SA	0.00	5.00	10.00	20.00
RPM	1250	1500	2000	2250

Table: 2. Experimental Results for Different Speeds with Gasoline

RPM	1250	1500	2000	2250
Power (kW)	5.3	6.8	8.7	8.4
s. f. c. (g/kWh	372.4	326	308	379

The detailed foreseen results for different variations along with the experimental results are shown in Table 3.The contrast is favorable with average deviation of (4.6%) in power and (- 2.87%) in sfc. This success in using the modified model to predict performance with gasoline, encouraged its use with other fuels which are considered as candidate alternative fuels for the S.I., such as methanol CH3OH, natural gas NG, synthetic gas from coal, and mixture of gasoline and hydrogen. The operating particulars of these fuels along with gasoline are shown in Table 4. Thus, further alterations in the modified computer program are carried out to take these specifics into account.

In addition to the basic three operating variables namely N, Φ and SA which were used with gasoline, the compression ratio rc is now added to represent the effect of fuel on knock requirements of the engine. Table 5 shows the values of these variables at the design point with six different fuels. Table 6 gives the overall picture of operation and performance at the design point for the different fuels.

Table 3. Power and sfc at different rpm for different modifications at Design point

Fig (2) shows the variation of brake power Pb with the equivalence ratio Φ, for various fuels. All the fuels manifest maximum Pb at stoichiometric A/F Φ =1 consistent with the ma

Table: 5. Design point for the fuels

Fuel	**Iso-Octan**	**Gasoline**	**CNG**	**H2 + Gasoline**	**Methanol**	**Syn. Fuel**
CR	9	9	15	9	13	14.5
Φ	1.2	1.2	1.1	1.3	1.3	1.1
SA	19	19	14	19	19	19
rpm	2500	2500	2500	2500	2500	2500

-ximum temperature. Fig (3) shows that the maximum η at 1500 rpm,a condition of part load but relatively low friction power.

Experimental		**Friction**		**Heat transfer**		**Valve timing**		**Prog. Combustion**		**deal**		**Modification**
s.f.c.	**Power**	**s.f.c**	**Power**	**s.f.c**	**Power**	**s.f.c**	**Power**	**s.f.c**	**Power**	**s.f.c**	**Power**	**rpm**
372.4	5.30	400.2	5.04	348.53	5.79	325.18	6.20	288.98	6.98	250.25	8.06	1250
326	6.80	331.10	6.65	289.76	7.60	269.50	8.20	244.098	9.02	220.99	9.97	1500
308	8.70	297.20	9.10	257.02	10.52	239.88	11.3	211.08	12.24	199.4	13.54	2000
379	8.40	348.8	9.22	294.52	10.92	275.2	11.7	256.49	12.55	218.09	14.55	2250

s.f.c = g/kWh Power=kW

Property	**Comm. R**	**RON**	**$\Phi_{mis\ fire}$**	**Φ_{pl}**	**Φ_n**	**$(O_2/F)_s$**	**H.V.,MJ/kg**	**MM., kg/kmol**	**R_c**
CH_3OH	Higher	107	-	0.9	1.4	1.6	24	34	13
$C_{1.1}H_{4.2}$	Higher	123	0.6	0.7	1.2	2.13	55	18	15
$C_{0.58}H_{0.8}O_{0.58}$	Lower	-	0.5	-	1.1	0.7	16.5	17.5	14.5
$C_{7.12}H_{14.56}$	-	97	0.9	0.9	1.3	10.97	44.7	104	9
2% H_2 + Gasoline	Higher	99	0.7	0.8	1.3	11.24	49.771	103	9

Table: 4. Operating Particulars of different fuels

The following figures show the off-design performance of the engine. Fig (1) shows the maximum brake thermal efficiency η at stoichiometric Φ, consistent with the reverse relation between η and bsfc.

Table: 6. Operating Variables and Results of Different Fuels at Design Point

Fuel	**C_8H_{18}**	**$C_{7.12}H_{14.56}$**	**$C_{1.1}H_{4.2}$**	**CH_3OH**	**$C_{.58}H_{.84}O_{.58}$**	**H_2 + Gasoline**
Φ	1.3	1.3	1.2	1.4	1.1	1.3
SA	19	19	14	19	19	19
N(rpm)	2500	2500	2500	2500	2500	2500
Brake Power (kW)	12.31	12.16	42.32	16.27	42.45	51.33
Torque (N.m)	48.50	47.85	43.32	61.75	43.40	52.30
BSFC(g/kWh)	303.49	311.06	255.03	575.40	811.20	335.80
%	27.7	27.45	31.33	27.89	29.70	24.80

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η

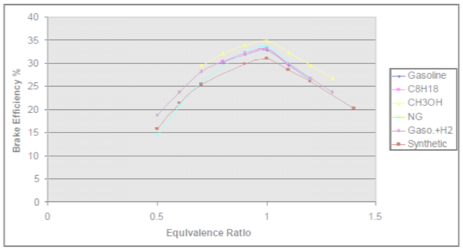

Fig. (1). Variation of brake efficiency with equivalence ratio for different fuels.

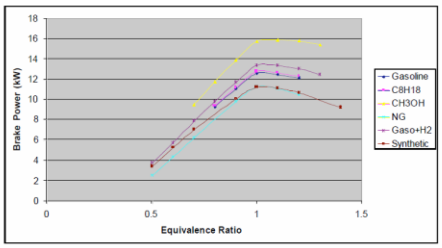

Fig. (2). Variation of brake power with equivalence ratio for different fuels.

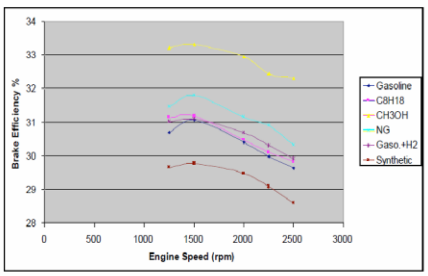

Fig. (3). Variation of brake efficiency with engine speed for different fuels.

8. Conclusion and Summary

1. Iso-octane produces more brake power than gasoline by 1.3%, It shows an increase in brake thermal efficiency η by 0.55%.
2. Natural gas produces less brake power than gasoline by 10%, It shows an increase in η by 13%.
3. For the same energy input, Methanol produces more brake power than gasoline by 20.8%, It shows an increase in η by 11%.
4. Gasoline-Hydrogen mixture produces brake power more than gasoline by 7%, It shows an increase in η by 2% .
5. Spark advance from 0-18º BTDC increases the brake power by 4.75% and the η by 4.9%. Spark advance from 18-28º BTDC increases the brake power by 2% and the η by 1.5%.
6. The ratio of brake power to the engine speed increases by 14.8%. At low engine speed the η increases by 1.9 %. At high engine speed the η decreases by 1%.
7. Synthetic fuel produces less brake power than gasoline by 12%, It shows a decrease in η by 2%.

Irrespective of the type of alternative fuel, there are hindrances of a structural nature to its implementation. The most vital innovation is the development of a reliable technology. The implementation of alternative fuels for transport requires proper implementation of new technology, also investment risks are high. Manufacturers are unlikely to take such risks until and unless a proper regulatory framework is established which enforces and supports the development of new technologies.

The role of policy-makers should be to reduce the uncertainty through necessary and timely policy measures, legislation and standards. Alternative fuels hold the future and are undoubtedly unconventional dependable source of energy.

Nomenclature

ABDC = After bottom dead center degrees
AETs = Alternative Energy Technologies
A/F = Air Fuel mixture
AO = Wide open valve area for both valves m3
B = Bore m
Pb = Brake power kW
bsfc = Brake specific fuel consumption g/kW.h
Btu = British thermal unit
BBD = Before bottom dead center degrees
CIE = Compression ignition engine
CNG = Compressed Natural Gas
CO = Carbon monoxide CO2 = Carbon dioxide
EVO = Exhaust valve open degrees
EGR = Exhaust gas recirculation
FORTRAN = Formula Translating System
GHG = Green House Gas
H/C = Hydrogen – carbon ratio
h_{fg} = Heat of vaporization kJ/kg
IVO = Inlet valve open degree
L = Length of the connecting rod m
LPG = Liquiefied Petroleum Gas
LNG = Liquified Natural Gas
MATLAB = Matrix Laboratory (Software)
MTBE = Methyl Tert Butyl Ether N = Engine speed rpm
NGV = Natural Gas Vehicle NOX = Nitrogen Oxides
OECD = Organisation for Economic Cooperation and Development
O.N. = Octane Number
OPEC = Organisation for Petroleum Exporting Countries
NG = Natural gas
p = Pressure M Pa
psi= Pound per square inch RON = Research octane number
rc = Compression ratio
S = Stroke m
S.I. = Spark Ignition SO2 = Sulphur dioxide
SA = Spark advance degrees
SIE = Spark ignition engine
TM = Intake manifold temperature K
T1 = Temperature at the start of the compression stroke Tsp = Spontaneous ignition temperature K
Urp = Internal energy of reaction of the fuel kJ/kg
V = Volume m3
Vd = Displacement Volume
VBDC = Volume at the bottom dead center m3
Vd = Displacement volume m3
VTDC = Clearance volume m3
GREEK LETTERS
η = Efficiency
Φ = Equivalence ratio
OTHER SYMBOLS
$=US Dollar

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