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Short Note

Green Energy Sources for Sustainable Development and Environmental Protection

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ABSTRACT

The consumption of energy has been increasing rapidly and in fact almost exponentially since the Industrial Revolution. To meet the growing demand of energy, there is at present the pressing need of alternative sources of energy in order to partially solve the present-day problems of the use of fossil fuels. The target is then to explore such energy system or systems that have no negative environmental, economic and societal impacts, which we mostly refer to as "green energy". The sources of green energy include the energy from sun, wind, biomass, geothermal, hydropower system etc. which will provide an important attribute for sustainable development. This article explains the practical relevance of deriving the energy from sources like ethanol, methanol, biodiesel, hydrogen energy, solar energy. Increasing the utilization of the sources of green energy to a maximum extent will definitely benefit the mankind in terms of their reliability and environmental protection ability. In view of this, an attempt is made to study the applicability of these green energies in our day-to-day life for sustainable development and environmental protection.

INTRODUCTION

Energy has become the prime commodity in modern civilization and the amount of energy consumption has become the indicator for the standard of living of a nation. It has long been recognized that the excessive use of energy has the adverse impact on the environment, economy, and society, from local air and water pollution (Table 1) to the threat of global warming (the mean temperature increase around the globe) and climate variability (the temperature fluctuations around the mean); and from the economic difficulties arising out of the rapid increase and swings in energy prices. The sustainable development of humanity and the economy with the security of energy has at present topped national agendas around the world. It is imperative to develop energy strategies, policies, and technologies to achieve this objective through an energy system(s) that have no observable (or net) negative impact on environment, economy, and society and such energy systems are being referred to as green energy (systems). At present, most of the energy requirement worldwide is met by the combustion of fossil fuels (*i.e.*, coal, petroleum oils, natural gas, etc. reported by IEA (2008), which has become an essential and integral part of modern civilization, being increasingly relied upon since the Industrial Revolution. Dincer and Rosen (2004) carried out a study only a very small proportion of the energy comes from nuclear and hydro power, and a much smaller portion from renewable energy sources, such as solar, wind, hydro, geothermal, tidal wave, and so on. The exclusive reliance on the combustion of fossil fuels has resulted in enormous amounts of harmful pollutant emissions to our environment, has caused severe degradation of the local and global environment,

Table 1: Pollutants emissions of CNG and LPG compared with petrol and diesel

Type of pollutants (lesser by)	CNG(%) compared to petrol and diesel	LPG(%) compared to petrol	LPG(%) compared to diesel
Carbon dioxide	25.0	15.0	10.0
Carbon monoxide	80.0	60.0	75.0
Nitrous oxide	40.0	33.0	40.0
Hydrocarbons	90.0	90.0	85.0
Particulates	NA	50.0	90.0

Source: Planning Commission 2008

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and has exposed the world population (from humans to animals and from plants to all forms of life on earth) to the hazards and risks created by the extensive use of fossil fuels mentioned by Adamson (2004). In addition to the health and environmental concerns, a steady depletion of the world's limited fossil fuel reserves also calls for alternative primary energy sources and new energy technologies for energy conversion and power generation that are more energy efficient than the conventional combustion engine with minimal or no pollutant emissions and add to sustainable development reported by Ganeshan (2008). Key requirements for sustainable development include societal, economic, and environmental sustainability, all related to the sustainability of energy systems by reducing in the use of only dependant fossil fuels. Alternatives to using fossil fuels include use of nuclear power, large-scale photovoltaic, solar thermal system, intensive biomass cultivation, wind turbines and large-scale hydroelectric projects etc.

India spends huge reserves of foreign exchange every year for importing crude and petroleum products. Sometimes, it exports molasses, which can be used to produce alternate fuels to meet needs of our transportation sector. Based on experiences in Brazil and USA, India can develop a sustainable and viable alternate fuel programme. For catering the growing needs of the society and because of the problems that are being faced due to the usage of the fossil fuels and due to its scarcity, the demand for the alternative sources of energy (green energy or sustainable energy) is growing day by day. This article discusses some of the alternate fuels mostly called as sources of green energy which are capable of overcoming the problems that are faced due to the usage of the fossil fuels.

Ethanol

Fuel ethanol is a high-octane, water-free alcohol currently used in Canada as an additive to gasoline. Most of the fuel ethanol is in concentrations up to 10% (10% ethanol/90% gasoline); there is also a small quantity of E-85 (85% ethanol/15% gasoline) used. Singh and Sai (2010) reported that Ethanol can be derived from different sources of biomass such as sugarcane molasses, beats, corn, sorghum, potatoes and others**.** On a world wide basis, out of the total annual production of 33.3 billion litres of ethanol, 68% is used as an automotive fuel, 21% is utilized for industrial purposes and the remaining 11% is used for beverages. Gupta (2003) mentioned that In India, the entire production of ethanol is used for industrial purposes and for producing beverages. Sundaram *et al.* 2014 mentioned that ethanol can be blended directly with methyl ester of vegetable oil to power CI engine.

Previous work on Ethanol as a fuel in India

Very early reported work was carried out in Indian Institute of Science, Bangalore in 1950s soon after the Second World War. Substantial interest was shown in this area during the end of 1970s and in the beginning of 1980s on account of steep rise in crude prices. Prasad *et al.* (2007) reported that almost all the national level technical institutions and technical universities embarked on research and development work pertaining to the use of ethanol in gasoline and diesel engines used in agricultural and transportation sectors

As a transportation fuel, ethanol can be used in the following ways:

- As an additive to gasoline-in USA typically using 10% ethanol (gasohol) and in Brazil normally 22%.
- As a component of reformulated gasoline both directly and /or in the form of ethyl tertiary butyl ether (ETBE)
- Blended with 15% (or sometimes more) gasoline known as E85.
- Mixed with ignition improvement additive to be used in diesel engines.

Adding ethanol to gasoline (gasohol) or as ETBE to reformulated gasoline does not require specially configured vehicles. Almost all existing vehicles will tolerate these fuels without problems and with likely advantageous emission benefits.

Infrastructural Requirements

Regarding transport and storage of ethanol, its property to absorb water has been an issue as well as problems with corrosion. Generally, no specially storage and dispensing equipment are required at ethanol refueling facilities, as dry ethanol is compatible with plain steel.

Ethanol will not be significantly degraded by small amounts of clean water, though the addition of water dilutes its value as a fuel. Partly for this reason, the primary use of ethanol in the transportation sector is expected to be as a fuel additive to conventional fuels. Fuel dispensers must have appropriate elastomers for ethanol and must not use plain aluminum components.

Challenges

The current size of the ethanol industry depends

significantly on laws and regulations that promote its use for air quality and energy security purposes, as well as tax incentives that lessen its cost to consumers. Without these, it is likely that the industry would shrink substantially in the near future. However, if the costs for fuel ethanol process can be decreased, or if gasoline prices increase, ethanol could increase its role in fuel consumption. Experience in Brazil has shown that prices compared to conventional fuels, as well as reliability of supply play a major role in consumer acceptance and hence market penetration.

Methanol

Methanol (sometimes called wood alcohol) can be made from various biomass resources like wood as well as from coal. However, today nearly all methanols are made from natural gas, because it is cheaper. Methanol is also very poisonous and very harmful, if swallowed. Methanol must not be confused with ethanol. As with gasoline, it is also wise to avoid skin contact with methanol, as it can pass through the skin.

Alcohol-fuelled Vehicles

Methanol is safer in case of accidental fire than gasoline, because it burns cooler. One problem is that the flame from a methanol fire is difficult to see in bright sunlight. Sometimes accidental fires are not detected immediately, because the fire is hard to see. Methanol contains about; half the energy of gasoline per gallon. Low energy per gallon means fewer miles per gallon of fuel, not less power. The decrease in range with methanol is not a problem for racing cars though, since all of the cars are using exactly the same fuel. Demirbas (2011) studied Methanol can be used as an alternative fuel in flexible fuel vehicles that run on M85 (a blend of 85% methanol and 15% gasoline). However, it is not commonly used because automakers are no longer supplying methanol-powered vehicles.

Methanol can be used to make methyl tertiary-butyl ether (MTBE), an oxygenate which is blended with gasoline to enhance octane and create cleaner burning fuel. MTBE production and use has declined because it has been found to contaminate ground water. In the future, methanol could possibly be the fuel of choice for providing the hydrogen necessary to power fuel cell vehicles.

Flexible Fuel Vehicles

Flexible fuel vehicles (FFVs) are specially designed vehicles that can operate on alcohol, gasoline or any combination of the two. Although, some vehicles run on pure alcohol, FFVs operate on alcohol blends for two main reasons (Table 2). Adding a small amount of gasoline improves the engine starting in cold weather and improves flame visibility in daylight. The alcohols used in FFVs are E85 or M85. FFVs are specially designed to tolerate the corrosive nature of alcohols. FFVs can run on gasoline when needed. The amount of energy in alcohol fuels is different than gasoline. The lower energy content of these fuels will result in fewer miles per gallon or a shorter driving range. Still with larger fuel tanks, FFVs often have driving ranges equivalent to conventional gasoline car.

Biodiesel: The alternate, vegetable-based fuel for diesel engine

Biodiesel is a cleaner-burning diesel fuel made from natural, renewable sources such as vegetable oils. Just like petroleum diesel, biodiesel operates in combustion-ignition engines. Biodiesel is made through a chemical process called trans-esterification whereby the glycerin is removed from the vegetable oil. It is produced from soybean or other vegetable oil or from used cooking oil (there are more than 4 billion gallons of waste cooking oil produced annually in the U.S., enough to replace 10% of fuel expenditures). It can be made from almost any

Table: 2. Comparative Properties of Green Enery with Fossil fuels

Property	Methanol	Ethanol	Gasoline	E85
Chemical formula	CH3OH	C2H5OH	C4 to C12	-
Octane No.	100	98-100	86-94	96
Lower heating value (Btu/lb)	8570	11500	18500	12500
Litre equivalent	1.8	1.5	1	1.4
Km/l as compared to gasoline	55%	70%	100%	72%
Fuel tank size	1.8	1.5	1	1.4
RVP (psi)	4.6	2.3	8-15	6-12
Air/fuel ratio	6.45	9	14.7	10
Vehicle power	4% more	5% more	standard	3-5% more

plant-derived oil. It decreases the solid carbon fraction of particulate matter (since the oxygen in biodiesel enables more complete combustion to CO_2), eliminates the sulphate fraction (as there is no sulphur in the fuel) (Table 2). Therefore biodiesel works well with new technologies such as catalysts which reduce the soluble fraction of diesel particulate but not the solid carbon fraction. Biodiesel reduces carbon monoxide, carbon dioxide, sulphur dioxide (one of the main causes of acid rain), hydrocarbons, benzene and particulate matter. It Increases NO_x levels (unless biodiesel is made from used cooking oil). The biodiesel industry is looking for additives that would reduce NOx levels (Table 3). It can be safely be blended with petroleum diesel. Biodiesel can be used in any diesel engine with little or no modification to the engine or the fuel system. It may results in a slight drop in fuel economy, but may extend the life of diesel engines. It is biodegradable. Would create new jobs and increases the income for farmers. It may provide a domestic renewable energy supply. It is safer to use than petroleum diesel-it has a flash point of 300 ^{o}F (vs. 125 ^{0}F for diesel). Can also be used as a fuel lubricity additive in diesel fuel.

Table 3: Emissions Characteristics of Bio-diesel compared to Petro-diesel

Emissions	B100 (100% bio-diesel) (%)	B20 (20% Bio-diesel) (%)
Regulated emissions		
Total unburned hydrocarbons	93	30
Carbon monoxide	50	20
Particulate matter	30	22
Nitrogen oxide	13	2
Non-regulated emissions		
Polycyclic aromatic hydrocarbons (PAH)	80	13
NPAH (Nitrate PAH)	90	50
Life cycle emissions		
Carbon dioxide	80	
Sulphur dioxide	100	

Hydrogen

Hydrogen has been used effectively in a number of internal combustion engine vehicles as pure hydrogen is mixed with natural gas. In addition, hydrogen is used in a growing number of demonstration fuel cell vehicles. Hydrogen and oxygen from air fed into a proton exchange membrane (PEM) fuel cell 'stack' produce enough electricity to power an electric automobile without producing harmful emissions. Hydrogen also can be used in modified internal-combustion engines with essentially pollution-free emissions described by Tiwari and Ghosal (2007). It can be produced in two basic ways: first, by steam reformation of natural gas or other hydrocarbon fuels, including coal and biomass fuels from agricultural feed stocks or waste materials: and second, by electolysis, using electricity supplied by a wide variety of sources, including renewable fuel sources. While electrolysis is ideal, it is not economically competitive at this time. Hydrogen will play an important role in developing sustainable transportation, because in the future it may be produced in virtually unlimited quantities using renewable resources.

Solar Energy

We have always used the energy of the sun as far back as humans have existed on this planet. Plants use the sun's light to make food. Animals eat plants for food. Decaying plants hundreds of millions of years ago produced the coal, oil and natural gas that we use today. So, fossil fuels are actually sunlight stored millions and millions of years ago. Indirectly, the sun or other stars are responsible for all our energy reported by Tiwari and Ghosal (2007) and Tayde (2012).

Solar Thermal Electricity

Solar energy can also be used to make electricity. Some solar power plants, like the one in California's Mojave Desert, have rows of solar mirrors arranged in what's called 'solar thermal power plants' that use this idea to make electricity for more than 350,000 homes. The problem with solar energy is that it works only when the sun is shining. So, on cloudy days and at night, the power plants cannot create energy. Some solar plants are a 'hybrid' technology. During the day time they use the sun. At night and on cloudy days they burn natural gas to boil the water so they can continue to make electricity. Sukhatme (2004) described Sunlight is reflected off 1,800 mirrors circling the tall tower. The mirrors are called heliostats and move and turn to face the sun all day long. The light is reflected back to the top of the tower in the centre of the circle where a fluid is turned very hot by the sun's rays. That fluid can be used to boil water to make steam to turn a turbine and a generator. The device uses the sunlight to change heat into mechanical energy in the turbine. The power plant will make enough electricity to power about 10,000 homes. Maycock (2003) mentioned that larger central tower power plants can make electricity for 100,000 to 200,000 homes

Solar Photovoltaic Energy

We can also change the sunlight directly to electricity using solar cells. Solar cells are also called photovoltaic cells or PV cells in short and can be found on many small appliances, like calculators and even on spacecraft. They were first developed in the 1950s for use on U.S. space satellites. They are made of silicon, a special type of melted sand reported by Chopra *et al.* (2004). These individual solar cells are arranged together in a PV module and the modules are grouped together in an array. Some of the arrays are set on special tracking devices to follow sunlight all day long. The electrical energy from solar cells can then be used directly. It can be used in a home for lights and appliances. It can be used in business. Solar energy can be stored in batteries to light a road side billboard at night or the energy can be stored in a battery for an emergency roadside cellular telephone when no telephone wires are around. Some experimental cars also used PV cells. They convert sun light directly into energy to power electric motors on the car. Solar panels are also used to provide power to satellites.

Solar Power Satellites

Shyam (2002) reported for energy in the future is to put huge solar power satellites into orbit around the earth. They would collect solar energy from the sun, convert it to electricity and beam it to earth as microwaves or some other form of transmission. The power would have no greenhouse gas emissions, but microwave beams might affect health adversely. And frequent rocket launches may harm the upper atmosphere. This idea may not be practical for another country, if at all.

Discussion and Suggestions

The sources of green energy those can give the solution when the supply of gasoline is exhausted are ethanol, biodiesel, CNG, LPG etc. But ethanol is the only fuel that can give the solution for many of the problems of the present-day that we are facing due to the fossil fuels (Table 4). Some of its very important features are: (1) it is renewable resource, facilitating reduced independence on oil imports. (2) Compared to conventional fuels, it has the potential to produce less emissions of air pollutants and especially life cycle emissions of greenhouse gases. (3) It has about 33% per liter lower energy density than gasoline, leading to a lower vehicle driving range.(4) As an octane enhancer in gasoline, it increases the volatility when mixed in the 0-20% range and unless off set by low volatility blending components tends to increase evaporative hydrocarbon emissions. (5) It absorbs water and will cause phase separation in gasoline mixtures if water comes into the distribution, storage or vehicle fuel system. (7) It tends to increase aldehydes emissions. (8) As an additive to gasoline. (9) As a component of reformulated gasoline both directly and/ or in the form of ethyl tertiary butyl ether. (10) It can be blended with 15% (or sometimes more) gasoline known as E85. (11) Mixed with ignition improvement additive to be used in diesel engines.

CONCLUSION

Based on the above advantages and the problems that are being faced by the other fuels to overcome certain

Table 4: Comparative studies of some green energy fuels

Fuel types	Engine issues	Storage issue	Availability	Environment impact
CNG	No modification to engine required	Large storage tank minimizes luggage capacity	Available mainly in Delhi and Mumbai	25% lower CO_2 emission as compared to petrol and diesel
LPG	No modification to engine required	Storage tank is smaller but still reduces luggage capacity	Available in around 619 stations mainly in Southern and western India	15% lower CO_2 and 50% lower particulate emissions as compared to petrol. 10% lower CO_2 and 90% lower particulates as compared to diesel
Bio-diesel	Minor modification required if the blend is beyond 25%	No issues as it goes into the normal fuel tank	Large scale crop is required but can be grown in waste land	For B100 fuel, 30% lower particulate emissions and 80% lower CO_2 for life cycle emissions as compared to diesel
Ethanol	Minor modification required if the blend increases beyond 24%	No issues in storage	Depends on sugarcane crop and the processing capacity	E100 fuel can reduce net CO_2 emissions up to 100% on a life-cycle basis and 22-50% on usage basis

crucial situations, ethanol is thought to be the best alternative fuel for the future.

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