RENEWABLE ENERGY SYSTEMS

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Hybrid Energy Systems

1.Introduction

Renewable energy sources dealt in various chapters are distributed systems of energy widely spread in the country that is most suitable for dispersed population located not reachable by state grid. It is inherent with renewable energy systems that energy supply is not continuous. Reason for this shortcoming is to be understood and solution searched.

2. Need for hybrid systems

Solar water heaters , air heaters, solar distillation and wax melters, PV arrays, PV pumps, operate at optimal efficiency for the months of April to September when solar radiation contain high energy flux. To meet the load demand during night and cloudy days, battery bank is provided. During winter, load demand shoots up and solar energy reduces, so designer is compelled to select large size equipment, PV arrays and battery bank. Similar situation is faced for a stand-alone wind power generating system, when wind speed drops below cut-in speed and Wind Turbine Generator (WTG) stops. For emergency, loads of hospitals, defense installations and communication services, a backup source (1) diesel generator, (2) gas turbine generator, (3) biogas, (4) small hydro, and (5) fuel cell is required. Two different energy systems installed at a location to ensure continuity of electrical supply is known as hybrid energy system. Thus, hybrid energy system provides an edge over the stand-alone and even grid interactive systems for reliability of energy supply and lower capital cost. However, engineer's selection of the backup source is done by maximum capacity of the prime energy source at peak energy demand period.

3. Types of hybrid systems

Few hybrid energy systems that are operative in prevailing Indian conditions in various states are given: It is assumed that a battery bank of a suitable size is installed as the storage tank for the period of low wind speed, during 'No Sun' cloudy day and night period. Correct choice for an option will include the parameters

(i) Available solar insolation at optimum array tilt,
(ii) Free wind velocity at 10 m or 20 m height,
(iii) Number of cattle available in a village or a cluster community.

- (A) PV – Diesel
- (B) Wind – Diesel
- (C) Biomass – Diesel
- (D) Wind – PV
- (E) Micro hydel – PV
- (F) Biogas – Solar Thermal
- (G) Solar – Biomass
- (H) Electric and electric hybrid vehicles

3.1 PV Hybrid with Diesel Generator

Renewable energy technologies are possible for electrification of remote villages including small hydro, wind, biomass and solar energy, yet solar PV lighting remains the most preferred. Such systems are used in Orissa, Assam, Sikkim, Jammu and Kashmir, and Uttarakhand. This power plant contains one PV array with a Diesel electric generator and a battery bank. Energy generatedfrom PV array feeds load demand and then charges the battery bank. Diesel generator keeps the battery fully charged and sometime supplies load demand when PV output is not sufficient and battery charge is low to supplement.

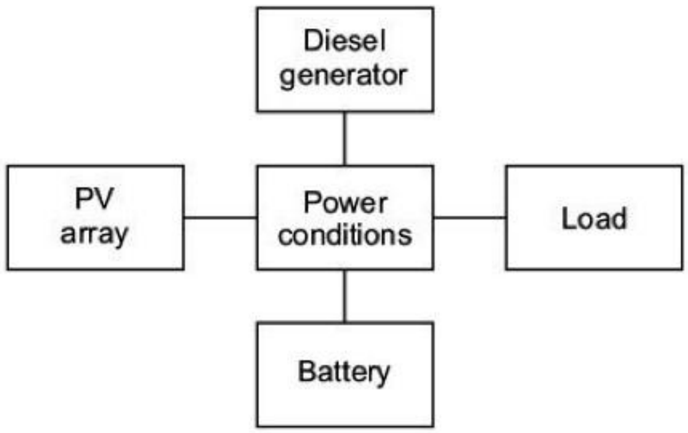


Figure 1 Block diagram of PV – Diesel hybrid power plant.

Figure 1 is a block diagram of such a power plant where Power conditioner performs three functions:

(i) To convert alternating current (ac) diesel generated output into direct current (dc) for charging battery bank.

(ii)To invert direct current (dc) from PV array and battery bank into ac for feeding load.

(iii) To regulate battery current and voltage for input from generator and output for load. Several experiments have been carried out to find where 10 per cent diesel fuel would be required with a given solar PV array area to replace 90 per cent of diesel fuel that would be consumed for a diesel system only. Experimental values have been used to draw a graph. Figure 2 shows 'life cycle cost' versus array area ($10^{3} \times m^{2}$).

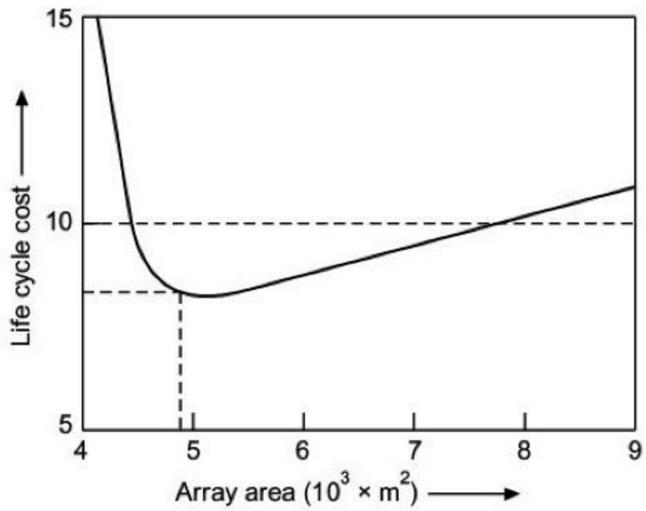


Figure 2 Graph of photo voltaic-diesel system i.e., life cycle cost and array area.

Graph indicates a minimum cost point corresponding to a cost effective design for a PV-diesel hybrid power plant where PV has replaced 90 per cent of the diesel fuel; had it been a diesel system only. Thus, a PV-diesel hybrid power plant ensures continuous power supply and is more
Cost effective as compared to stand alone PV system or stand-alone diesel.

3.2 Wind-Diesel Hybrid System

Remote coastal areas where wind speed is sufficient to operate a wind turbine but there is no state grid supply, wind generators are installed to electrify the area. Wind energy being intermittent a backup of diesel generator is required to maintain 24 hour power supply. Thus, wind-diesel hybrid system is installed to supply electric power to emergency load of hospitals, communication services, and defence, commercial and domestic load. Wind-Diesel hybrid system constitutes components, wind turbine, diesel generator, Controller battery and the load, detailed in Figure 3.

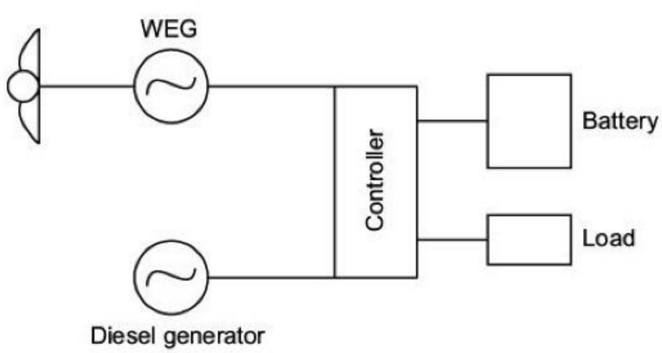


Figure 3 Wind-diesel hybrid system.

During favorable wind 400 V ac is delivered to the controller. The controller converts AC voltage to 120 V dc for charging the battery and it also controls the current required for its charging. Controller also ensures continuous power supply to the load. As the wind speed drops the lower limit, WTG stops and the diesel generator automatically starts to supply energy to the load and also for battery charging.

Thus, wind-diesel hybrid system ensures maximum utilization of free wind energy and continuity of power supply in remote inaccessible areas.

3.3 Biomass-Diesel Hybrid System

Combustion is a common process in biomass conversion technology. Application of combustion process is for solid fuels either from cultivated biomass or waste biomass. Biomass is widely available in hills and remote forest areas but becomes scarce during snowy winter. When its supply stops and stock dwindles, energy route of biomass to electrical energy by incineration suffers a setback. This system needs a backup by diesel power electric generator to meet the known lighting and plug loads of residences, commercial establishments, hospitals and other life sustaining loads. Essential components of this hybrid configuration are:

(a) 25 kW biomass generator.

(b) Battery bank of 1000 Ah capacity

(c) 15 kVA diesel generator.

A biomass-fired steam power plant is made hybrid with a diesel generator along with a controller, battery bank and load is shown in Figure 4.

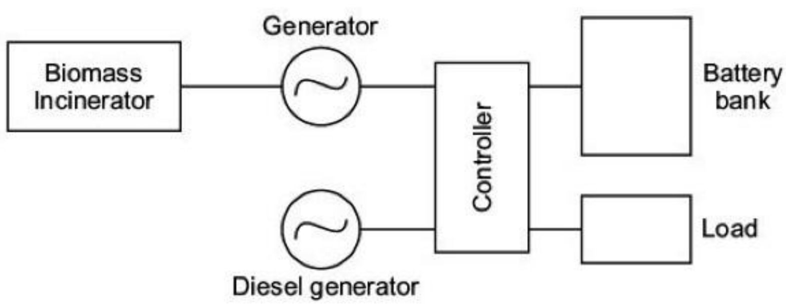


Figure 4 Biomass-diesel hybrid system.

To operate this system, economic viability is necessary by utilizing biomass generator to the full capacity and minimum use of diesel generator, for essential and lifesaving load during crisis period of biomass availability.

3.4 Wind-PV Hybrid System

Wind and solar hybrid energy systems are located in open terrains away from multistorey buildings and forests. Locations are selected in those areas where the sunshine and wind are favorable for more than 8 months during a year. A schematic wind-PV hybrid system is shown in Figure 5. During the day when sun shines, the solar photovoltaic plant generate dc electric energy conditioner provided, converts dc to ac and supplies power to the load. During favorable wind speed, wind turbine generator produce ac electrical power. It supplies power to the load and excess energy after conversion to dc is stored by the battery bank. The plant may operate as stand-alone load or may be connected to the state grid.

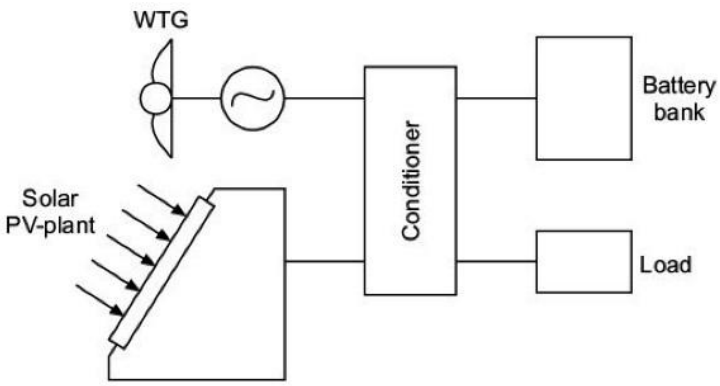


Figure 5 Wind-PV hybrid system.

3.5 Micro Hydel-PV Hybrid System

Micro hydel (up to 100 kW) power stations are low head (less than 3 m) installations and provide decentralized power in mountain regions, also in plains on canal falls. In remote areas of J & K, boarder districts of Arunachal Pradesh micro hydro power plants are the only source of energy. With the help of micro hydro power, rural electrification can be achieved besides providing power for pumped irrigation and grinding mills. In Arunachal Pradesh, 425 villages are being electrified by completing 46 small/ micro hydro power projects. However, there are 1058 villages which cannot be illuminated by micro hydel projects as at several locations, head is very low, while at other, quantity of water is small. Solution is to provide micro hydel-PV hybrid system as sunshine is available practically at all locations. Portable micro hydel sets of 15 kW capacities are installed with solar PV panels to complement each other as given in Figure 6.

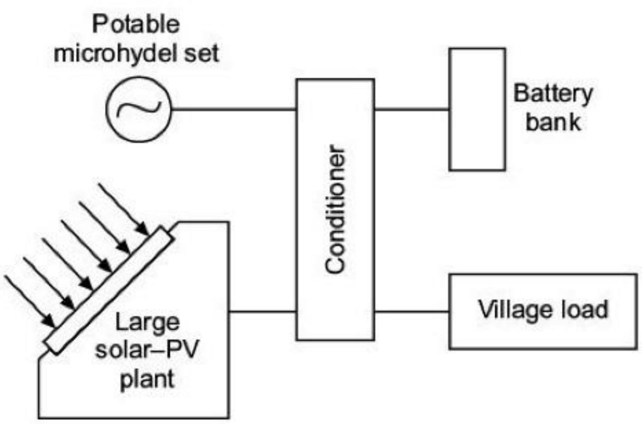


Figure 6 Micro hydel-PV hybrid system.

Micro hydel systems are provided with small dam store water to be used during night when solar PV panels stops power supply. A battery bank may be provided for emergency power supply. A battery bank may be provided for emergency power supply wherever required. Load management is carried out to maintain continuity of supply for 24 hours matching with the capacity of generating equipment.

3.6 Biogas-Solar Thermal Hybrid System (A Case Study)

It is a case study of milk chilling Centre located in a remote village Vasna Margia in Kheda district of Gujarat. Major components of this system are:

(i) Biogas plant to be operated with an input of 300 kg cow dung daily.

(ii) One 5 H.P. dual fuel engine. Initially it starts with 100 per cent diesel fuel. Subsequently, engine switches to dual fuel mode with fuel ratio 80 per cent biogas and 20 per cent diesel.

(iii) Flat plate solar collector is installed on the roof of a building for the supply of hot water (100 litres per day at 60 ° C) required for cleaning the cans and milk chilling equipment parts.

(iv) An insulated water storage tank placed over the building connected to the solar collector. Biogas is generated in a KVIC type floating dome vertical design plant with a capacity of 12 cu m/ day gas production.

Biogas from the plant is taken to milk chilling centre (Figure 7) through a G.I. pipeline.

To begin operation, duel fuel engine is started where power transmission to the chilling plant is obtained with a common shaft coupled to the engine. This shaft further operates refrigeration compressor, chilled water circulating pump and air blower detailed in Figure 7.

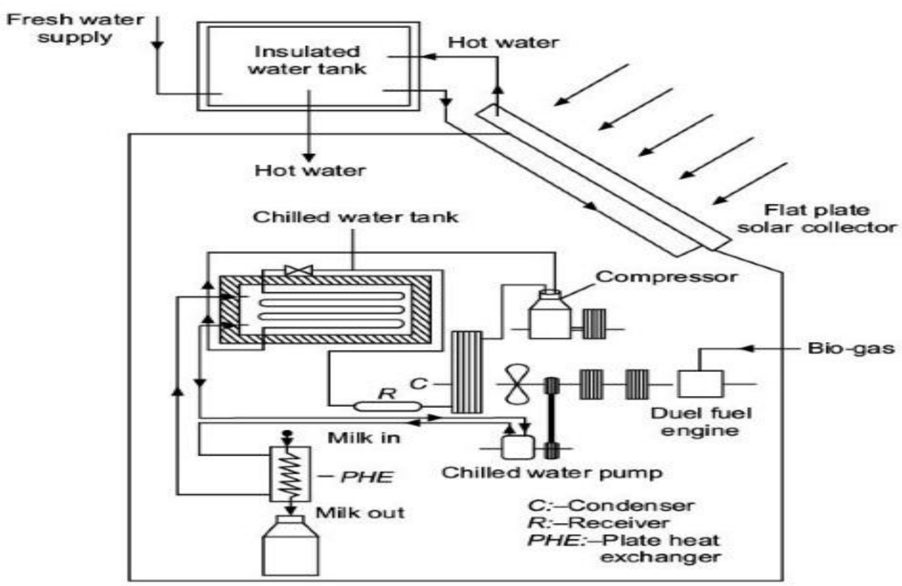


Figure 7 Schematic of milk chilling centre powered by Biogas and solar energy.

With the successful commissioning of this plant, milk cooperative society has become economically viable and milk producing farmers of the area are earning well. Really a combination of two renewable source of energy, i.e., biogas and solar thermal has proved a boon for remote villages.

3.7 Solar-cum-Biomass Dryer Hybrid (A Case Study)

Energy is required for mechanical drying of agricultural products in rural areas where grid electric supply is scarce. Solar and biomass are two main renewable sources of energy that may be used for drying of spices, herbs, and agricultural products for commercial production at low cost. Analysis showed that traditional drying, i.e., open sun drying, dried the turmeric rhizomes in 12 days while solar cum biomass dryer took only 1.5 days and produced better quality products in terms of colour, taste and texture. Selecting right drying technique is necessary in tropical regions where herbs and spices are harvested during winter or rainy season. The solar-cum-biomass dryer was developed at I.I.T. Delhi for 15– 18 kg capacity of turmeric rhizomes and other such products. The dryer has two parts: (i) solar dryer (ii) biomass burner as shown in Figure 15.8.

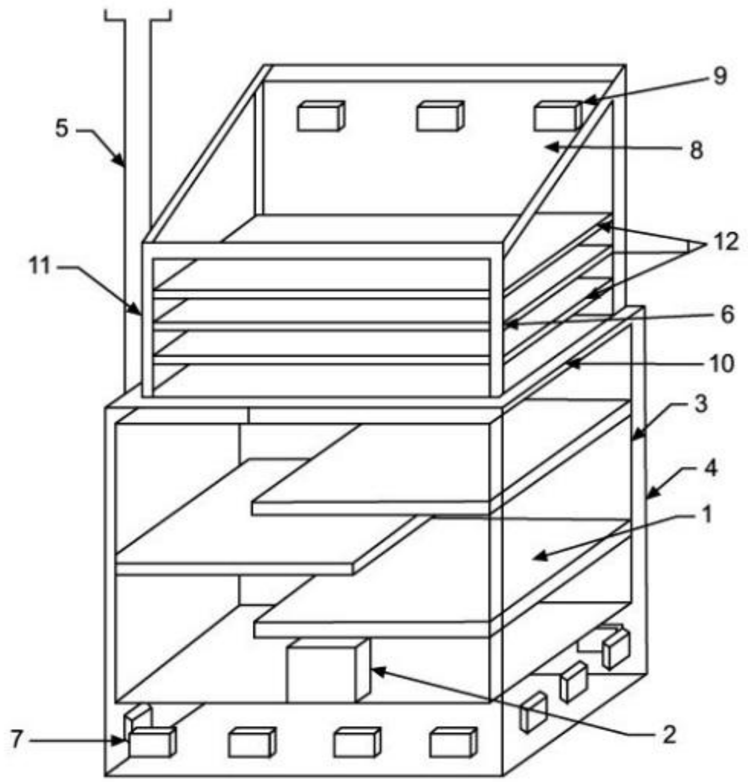


Figure8 Schematic diagram of solar-cum-biomass dryer.

Solar dryer

It consists of single glazed (2 mm thick) solar dryer mounted on a rock slab supported on a brick wall chamber. Top glass surface is inclined at an angle of 28.5 ° to capture maximum solar radiation at Delhi (latitude 28 ° 32 ? N during winter). There are three drying trays of wire mesh with a drying area of 0.94 m^2 each. Three adjustable vents are at the top of the dryer. Two doors are at the front for unloading the products.

Biomass burner

Biomass burner is a rectangular box. A door at the bottom is to feed the biomass and the control airflow for combustion. There is a iron grate for burning biomass. Exhaust gases exit through a chimney. Three metal baffle plates are above the iron grate to lengthen the flow path of combustion gases. A brick chamber encloses the burner which is covered with a rock slab to maintain correct air temperature. Dryer uses solar energy when solar radiations are more than 100 W/m2. When solar radiations fall on glass surface, these are absorbed resulting in increase of dryer temperature. Heated air inside the cabinet goes upward; picks up moisture from the product and goes out from the vents. It reduces pressure inside the cabinet an ambient air is drawn into the dryer through inlet holes. A continuous flow of air is thus established. During period of low or zero solar radiation, biomass burner is used for back up heating. Combustion gases warm the air as it moves over the outer surface. Warm air rises up in the drying chamber; evaporating and picking up moisture from turmeric as it passes through the trays and then escapes through vents. Temperature inside the dryer is controlled to avoid burning of product.

Dryer efficiency

Thermal efficiency over an entire drying trial (h) is the ratio of the energy used to evaporate the moisture from the crop product to the energy supplied to the dryer. With this dryer, both solar radiation and biomass supplied the energy, so

$$\eta = \frac{W\lambda}{IA + \mathrm{cm}}$$

Where W is the mass of water evaporated (Kg), l is the latent heat of vaporization (MJ kg^{-1}), I is the total radiation on the dryer (MJ m^{-2}), A is the solar collection area (m^{2}), c is the calorific value of biomass (MJ kg^{-1}), and m is the mass of used biomass (kg). As a test case, 8 kg of fuel wood (calorific value 28.7 MJ kg^{-1}) was burned. Solar biomass dryer removed 12.6 kg of water to dry 15 kg of turmeric to moisture content of 9 per cent (dB). Overall thermal efficiency of the dryer is calculated to be 28.11 per cent. Quality of product maintained in this dryer where as in open sun drying, it gets deteriorated.

4 Electric and hybrid electric vehicles

Electric vehicles are propelled by an electric motor powered by rechargeable battery packs. These vehicles need not have Internal Combustion Engines (IEC) system, the drive train and fuel tank. Electric motor replaces the engine and it gets power from rechargeable batteries through a controller. The electronic motor controller provides electric power to the motor based on inputs from accelerator. Electric power is delivered from battery pack, which is like the fuel tank of an electric (e) vehicle. However, they are slow in speed and move only up to 80 km on a charge. Full battery recharge takes nearly four hours. A hybrid electric vehicle combines a conventional internal combustion engine with an electric propulsion system. Presence of electric power train is intended to achieve better fuel economy than conventional vehicle or better performance. Most common of HEV is the hybrid electric car. Hybrid vehicles use both petrol and electric propulsion systems. In such vehicles, the electric motor provides a boost during starting and is recharged during vehicle operations. This cuts emissions significantly and improves fuel economy.

4.1 E-Vehicle Need

E-vehicle are gaining popularity concerning to: (i) High oil prices (ii) Greenhouse gas emissions (iii) Ambient air quality Concern over high oil prices and stringency in pollution and climate regulations have spurred new interest in e-vehicles. These are fuel-efficient, as, technically conversion of electrical energy into motive power is more efficient than burning fuel in an internal combustion engine. According to California Air Resource Board, fuel efficiency of an e-vehicle is three times higher than convention car. As electricity costs less than oil, operating cost per km falls to a fraction of a petrol car.

4.2 Emissions

E-vehicles emit nothing from their tail pipe. But the emissions from power generation are accounted for in the life cycle assessment of e-vehicle. Reva electric car company in UK showed when emissions of power stations wereincluded; the vehicle emitted 63 g CO2 per km. The best hybrid car gives 104 g CO2 per km. A UK study said that the life time emission of an e-vehicle is 3 times less than average emission from internal combustion engines CO2 emission per km from e-cars and hybrids. (Emission from power plants and internal combustion engines) accounted for are given in Figure 9.

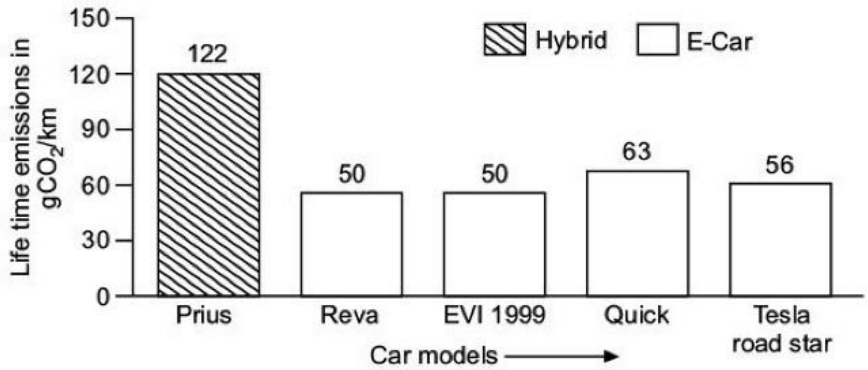


Figure 9 CO_2 emission per km e-cars and hybrids.

The other advantage of an e-vehicle is that there are no oil filters, air filters, spark plugs and radiators which need maintenance.

4.3 Limitations

Widespread use of battery operated vehicles is constrained by high prices, limited driving range, bar on maximum speed and battery efficiency. In India, most e-vehicles run on lead-acid batteries which provide short bursts of power to starter motors in cars. Also, lead is a known environmental hazard with serious health consequences. Lead-acid batteries will have to give way to lithium-ion batteries that improve performance four times over. Lithium ion is currently a dominant battery technology in portable applications. It provides the highest energy density of all rechargeable systems. REVA NXR is a new lithium-ion powered e-car claims that a first charge for 90 minute would offer a range of 320 km a day. The biggest challenge of e- vehicle industry is to produce batteries that can store large amount of energy that can be released and recharged quickly.

5 Hydrogen-powered-electric vehicles

Hydrogen is a clean energy carrier that can replace liquid and gaseous fossil fuels. Hydrogen can be used to power electric vehicles for longer distance, better speed, and acceleration and cost comparable with fossil fuel driven vehicles. Conversion of hydrogen to electricity is achieved through fuel cells. Fuelcells are an electrochemical device that converts chemical energy of hydrogen directly into electricity and heat without combustion. Fuel cell systems operate on pure hydrogen and air/ oxygen to produce electricity with water and heat as by-products. A phosphoric acid fuel cell (PAFC) is suitable for hydrogen powered electric vehicles. In India, BHEL has field tested them and commercially available in 40 kW, 200 kW and more sizes. Around Ajanta caves (Maharashtra), fuel cell operated bus ply within 7 km route to avoid pollution. Fuel cell operated vehicles are eco-friendly as it eliminates noise, SO2 and nitric oxide emissions.

5.1 Clean Mobility Options

Low speed e-vehicles with power less than 250 W and speed less than 25 kW/ h are exempt from Central Motor Vehicle Act and Rules. These are not categorized as motor vehicles, so driving licenses are not required. E-vehicles are part of the solution to air pollution and climate change. The e-vehicles will truly become zero emitters when these are charged with electricity from renewable sources such as solar and wind.

Questions

1. Define hybrid energy systems. What was the need for hybrid systems?
2. Discuss different types of hybrid systems.
3. Differentiate between wind-diesel hybrid system and wind-PV hybrid system.
4. Discuss a case study of installed hybrid energy systems in your city/ state.
5. Discuss in brief, how with the help of hybrid system vehicle emission can be controlled?

Biomass Power

1. Introduction

Biomass is a renewable source of fuel to produce energy because: waste residues will always exist – in terms of scrap wood, mill residuals and forest resources; and. properly managed forests will always have more trees, and we will always have crops and the residual biological matter from those crops.It is a derivative of solar energy as plant grows by the process of photosynthesis by absorbing $CO_2$from the atmosphere to form hexose expressed as

$$6CO_2 + H_2O \xrightarrow[\text{photosynthesis}]{\text{sunlight}} C_6H_{12}O_6 + 6O_2$$

Biomass does not add CO_2 to the atmosphere as it absorbs the same amount of carbon in growing the plants as it releases when consumed as fuel. It is a superior fuel as the energy produced from biomass is 'carbon cycle neutral'.Biomass fuel is used in over 90% of rural households and in about 15% urban dwellings. Agriculture products rich in starch and sugar like wheat, maize, and sugarcane can be fermented to produce ethanol (C_2H_5OH). Methanol (CH_3OH)is also produced by distillation of biomass that contains cellulose like wood and bagasse. Both these alcohols can be used to fuel vehicles and can be mixed with diesel to make biodiesel.

2. Biomass power operating principle

Biomass power as described is another synonym of bioenergy. Different types of conversion techniques of this process.

1. Densification of biomass
2. Combustion and incineration
3. Thermo-chemical conversion
4. Bio-Chemical conversion

3. Combustion

Direct combustion is the main process adopted to utilise biomass energy. It is burnt to produce heat utilised for cooking,space heating, industrial processes and for electricity generation. This utilisation method is very inefficient with heat transfer losses of 30-90% of the original energy contained in the biomass. The problem is addressed through the use of more efficient cook-stove for burning solid fuels.

4. Fermentation

There are two forms of biochemical conversions:

4.1Anaerobic digestion or Anaerobic Fermentation

This process converts the cattle dung, human wastes and other organic waste with high moisture content into biogas (gobar gas) through anaerobic fermentation in absence of air.Fermentationoccures in two stages by two different metabolic groups of bacteria. Initially the organic material is hydrolysed into fatty acids, alcohol, sugars, H_2 and CO_2. Methane forming bacteria then converts the products of the first stage to CH_4 and CO_2; in the temperature range 30– 55 ° C. Biogas produced can be used for heating, or for operating engine driven generators to produce electricity. Fermentation occurs in a sealed tank called 'digester' where the sludge left behind is used as enriched fertilizer.

4.2 Ethanol Fermentation

Ethanol can be produced by decomposition of biomass containing sugar like sugarcane, cassava sweet sorghum, beet, potato, corn, grape, etc. into sugar molecules such as glucose ($C_6H_{12}O_6$) and sucrose ($C_{12}H_{22}O_{11}$).
Ethanol fermentation involves biological conversion of sugar into ethanol and CO_2.

$$C_{12}H_{22}O_{11} + H_2O \rightarrow 2C_6H_{12}O_6$$

$$C_6H_{12}O_6 \xrightarrow{\text{Fermentation}} 2C_2H_5OH + 2CO_2$$

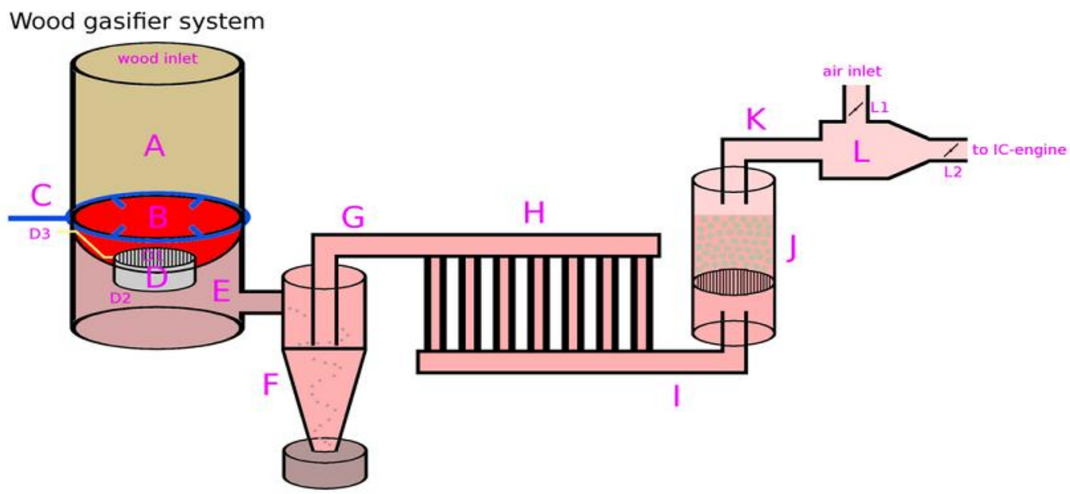
Ethanol has emerged as the major alcohol fuel and is blended with petrol.

5. Pyrolysis

Biomass is heated in absence of oxygen, or partially combusted in a limited oxygen supplyto produce a hydrocarbon,rich in gas mixture(H_2, CO2, CO, CH4 and lower hydrocarbons), oil like liquid and a carbon rich solid residue (charcoal).

The pyrolitic or bio – oil produced can easily be transported and refined into a series of products similar to refining crude oil.There is no waste product, the conversion efficiency is high(82%) depending upon the feedstock used, the process temperature in reactor and the fuel/air ratio during combustion.

A wood gasifier is a gasification unit which converts timber or charcoal into wood gas, a syngas consisting of atmospheric nitrogen, carbon monoxide, hydrogen, traces of methane, and other gases, which - after cooling and filtering - can then be used to power an internal combustion engine or for other purposes.Historically wood gas generators were often mounted on vehicles but present studies and developments concentrate mostly on stationary plants.



6. Biogas

Biogas is a renewable energy derived from organic wastes such as cattle dung, human waste, etc. It is a safe fuel for cooking and lighting.Left – over digested slurry is used as enriched manure in agriculture lands.Biogas is dependent upon many factors like temperature, pH value, seeding, retention time, C/N ratio.

Dependency Of Biogas On Temperature
Temperature affects bacterial activity.it slows down below 20^{o}C and stops at 8^{o}C.In general in cold region a solar canopy is build to maintain desired temperature.
Also Biogas is affected by certain other parameters like pH value, carbon to nitrogen ratio.

7. Wood stoves:

A wood-burning stove is a heating appliance capable of burning wood fuel and wood-derived biomass fuel, such as wood pellets. Generally the appliance consists of a solid metal (usually cast iron or steel) closed fire chamber, a fire brick base and an adjustable air control. The appliance will be connected by ventilating stove pipes to a suitable chimney or flue, which will fill with hot combustion gases once the fuel is ignited. The chimney or flue gases must be hotter than the outside temperature to ensure combustion gases are drawn out of the fire chamber and up the chimney. Many wood-burning stoves are engineered such that they can be converted to multi-fuel stoves with the addition of a grate.

1. Operation:

Keeping the air flowing correctly through a wood-burning stove is essential for safe and efficient operation of the stove. Fresh air needs to enter the wood compartment to provide oxygen fuel for the fire; as the fire burns, the smoke must be allowed to rise through the stove pipes, and exit through the chimney. To regulate air flow, there are damper devices built into the stove, flue, and stove pipes.

By opening or closing the dampers, air flow can be increased or decreased, which can fan the fire in the wood compartment, or "dampen" it by restricting airflow and reducing the flames. The dampers can usually be accessed by turning a knob or a handle attached to the damper, found outside the stove or stovepipe. One of the uses of the dampers is to increase airflow into the wood compartment to raise flames and thus the temperature of the stove, to temporarily create a high heat for cooking.

High heating efficiencies on closed appliances can only be attained by controlling the supply of air to the fire chamber (operating the air control correctly). It is not recommended to leave the air control fully open, except when helping the chimney/flue heat up initially. A fully open air control will lead to more heat being sent straight up the chimney rather than into the room (which reduces efficiency). The biggest problem with leaving the air control fully open is “over firing”. Over firing is caused when too much heat is generated within the fire chamber, which will lead to warping, buckling and general damage to the stove and its internal components. Individual stoves will have their own quirks, so it is necessary to learn each new stove's settings.

Modern building techniques have created more airtight homes, forcing many stove manufacturers to recommend that their stoves be installed with outside air intake. Outside air ensures that stoves will run more efficiently, and also removes the need for cold air for the combustion process to pass through the living space, thus reducing "draughts", and improving comfort of the occupants. These designs are called "room sealed stoves" or "external air supply stoves."

2. Fuel

2.1 Hardwood or softwood:

Firewood is sometimes purchased in English-speaking countries in a quantity called a cord. Each cord of firewood is 128 cubic feet of stacked firewood. A "standard cord" of stacked firewood has dimensions of 8 feet long, 4 feet high and 4 feet deep. Firewood is purchased by the cord, or by a fraction of a cord. Alternatively, it may be bought by the weight or by volume. The best fuels are oak wood, ash wood and beech wood, when well seasoned and cut small enough to fit into the grate of the stove.

When purchasing, cutting, or collecting firewood, it is crucial to be aware of the difference between hardwood and softwood. Both hardwood and softwood have the same energy content (by mass) and will provide similar energy outputs. However, the essential difference will be in the rate at which the fuel burns. Hardwoods derived from slow-growing broadleaf trees such as oak and ash will burn at a slower rate, resulting in sustained output. Softwoods are derived from evergreen trees such as conifers, which are fast growing.

They burn at a far faster rate. A disadvantage of softwood is that it creates more soot and other deposits on the inside of the wood stove, chimney, and flue therefore requiring more frequent cleanings.

The difference in practical use is significant, and it is important to take it into account for both heating and cooking purposes. Hardwood is most often preferred for heating since it burns over a longer period, and produces a consistent temperature as it burns. Hardwood also creates a greater amount of ash as it burns, producing a bed of ash coals, which help retain heat as firewood burns.[1] Softwood, in contrast, is often preferred for cooking, since it burns quickly and produces high heat. Hardwood and softwood may be used together in a woodstove to accomplish both heating and cooking purposes by adding softwood on top of hardwood that is already lit. Softwood is also used for kindling.

2.1.1 Moisture content

Dry wood produces more usable heat than wet wood, since the energy contained in evaporated water is lost up the chimney. Freshly cut wood (known as green lumber) has high moisture content. Green wood of ash trees contains 35% moisture and green poplar contains 65% moisture. Apart from producing very low heat outputs, the flame temperature is also reduced. This causes unburned creosote. Creosote leaves the burning wood as a gas, and cools to a liquid in the chimney, where it collects on the interior. This oily liquid coats the inside of the chimney and stove pipes. It collects soot and other combustion particulates. A buildup can reduce the draft (airflow) in the chimney. The chimney soot can then be ignited by rising embers, causing a chimney fire.

For best results firewood should have a moisture content of less than 20%. The process of removing the excess moisture is called seasoning. Seasoning by air-drying the wood can take up to two years. Wood is dried in outdoor well-ventilated covered structures. With interest and usage of wood burners at an all-time high, some companies are now using large kilns to quickly dry their wood.

2.2 Multi-fuel models

Multi-fuel stove designs are common in the United Kingdom, Ireland and Europe. They burn solid fuels only, including wood, wood pellets, coal and peat. They are typically made of steel or cast iron. Some models are also boiler stoves, with an attached water tank to provide hot water, and they can also be connected to radiators to add heat to the house.

There are also stove models that can switch from wood fuel to oil or gas sources that are installed in the house to supply heat to a separate water boiler.[2] Stoves that readily convert to either oil or gas in addition to wood fuel have been manufactured in North America and Europe since the early 20th century, and are still manufactured. In some models, the oil or gas may fuel the stove through a pipe connection leading to a "pot burner" in the rear of the firewood compartment in the stove.

2.3 Catalytic and non-catalytic stoves

As the temperature of the burning fuel/air mixture above the fire falls, the combustion process ceases. This means that the combustion gases often have both oxygen and fuel remaining uncombined in them. The combustion process can be continued at a much lower temperature in the presence of a catalyst. This reduces atmospheric pollution and may add to efficiency depending on the layout.

Catalytic wood stoves typically have a catalytic device built into the top of the stove, at the base of the stove pipe. The catalyst is held in a honeycomb metal lattice that re-ignites smoke from the fire as it rises to exit through the flue. In this way, the smoke itself becomes an additional source of fuel, which not only results in fewer emissions but improves heating efficiency.

A catalyst will start burning the smoke coming from the fire when it has reached a temperature of between 350 and 600F. At this point, the catalyst is said to "light-off". In some models, the catalyst will begin to glow when the temperature rises above 1000F.

It is possible though difficult to retrofit a catalytic converter to older stoves models, and retrofits rarely perform well. However, a drawback with catalytic converters is that (as when fitted to automobiles) they have a limited life before needing to be replaced, although new catalysts often last 5 - 10 years. More modern wood stoves are designed from the outset with an integral secondary combustion chamber. This mixes exhaust gases (smoke and particulates) with preheated fresh air and thus re-burns otherwise wasted fuel. The end result is similar, with much reduced emissions and increased fuel efficiency; stoves utilizing this design are often marketed as clean-burning stoves and exempted from smoke control regulations.

2.4 Paralyzing stoves

In a conventional stove, when wood is added to a hot fire, a process of pyrolysis or destructive distillation begins. Gases (or volatiles) are evolved which are burned above the solid fuel. These are therefore the two distinct processes going on in most solid fuel appliances. Air has to be admitted both below the fuel and above the fuel to enable complete combustion and to maximise efficiency. The correct balance is difficult to achieve in practice and many wood burning stoves only admit air above the fuel as a simplification. Often the volatiles are not completely burned resulting in energy loss, chimney tarring and atmospheric pollution.

To overcome this, the pyrolysing stove has been developed. The two processes go on in separate parts of the stove with separately controlled air supplies. Most stoves designed to burn wood pellets fall into this category.

Most pyrolysing stoves regulate both fuel and air supply as opposed to controlling combustion of a mass of fuel by simple air regulation as in traditional stoves. The pelleted fuel is typically introduced into the pyrolysing chamber with a screw conveyor .This leads to better and more efficient combustion of the fuel.

The technology is not actually new, it has been used for decades in industrial coal fired boilers intended to burn coal with high volatile content.

3 Safety and pollution considerations

3.1 Safety

Correct air flow and ventilation are also critical to efficient and safe wood burning. Specific requirements will be laid down by the stove manufacturer. Legal requirements for new installations in the UK can be found in Building Regulations Approved Document J, Section 2, Table 1 "Air Supply to solid fuel appliances".

The safe operation of a wood-burning stove requires regular maintenance such as emptying ash pans (containers) beneath the wood grate. Routine cleaning of the stove pipes and chimney is also needed to prevent chimney fires. Creosote and soot gradually build up in stove pipes and chimneys. This can damage the chimney and spread fire to the surrounding structure, especially the roof. When soot blocks the airflow through the stove pipes or chimney, smoke can back up in the stove pipes and into the house through the stove.

The basic principle of controlling combustion by reducing the air supply means that very often there is reduction zone/conditions within the stove. This means that carbon dioxide is often "reduced" to carbon monoxide, which is highly poisonous and must not be allowed to escape into the home. This can occur if the stove or chimney has not been cleaned or there is insufficient ventilation. Carbon monoxide detectors or alarms should always be installed according to manufacturers' recommendations where a wood stove is in use. Smoke detectors do not detect carbon monoxide.

Fuel accelerants such as coal, grease, oil, gasoline, kerosene, plastics, and so on, also must never be added to firewood in a wood stove, since the flames produced may easily overwhelm the wood compartment and stove pipes and create a house fire.

3.2 UK smoke control areas

Under the United Kingdom's Clean Air Act, local authorities may declare the whole or part of the district of the authority to be a smoke control area. It is an offence to emit smoke from a chimney of a building, from a furnace or from any fixed boiler if located in a designated smoke control area. It is also an offence to acquire an “unauthorized fuel” for use within a smoke control area unless it is used in an “exempt” appliance (“exempted” from the controls which generally apply in the smoke control area). The current maximum level of fine is £1,000 for each offence.

In order to comply with the Clean Air Act in "smoke control areas", an exempt appliance or fuel must be used.

3.3 US pollution control requirements

The United States Clean Air Act requires that wood stoves be certified by the Environmental Protection Agency (EPA). These devices meet a particulate emissions standard of no more than 7.5 grams per hour for non-catalytic wood stoves and 4.1 grams per hour for catalytic wood stoves.[7] Washington State has stricter requirements of a maximum of 4.5 grams per hour. However, the EPA has had no mandatory emission limits for pellet stoves, indoor or outdoor wood boilers, masonry stoves and certain types of wood stoves that are exempt from EPA regulation. EPA is developing new regulations and in 2015, these will begin to come into effect, establishing mandatory emission limits for almost all wood-burning appliances (fireplaces, chimeneas, and some other special appliances will still be exempt).

3.4 Justa stoves, rocket stoves and haybox stoves

In some places, such as the Caribbean, Central America and South America, many houses have wood-burning stoves that are used indoors without any means of proper ventilation. Smoke stays in the house, where it is breathed in by the residents, harming their health. Nearly 2 million people are killed each year by indoor air pollution caused by open-fire cooking, mostly women and children, according to the World Health Organization (WHO). The cutting of large amounts of firewood also endangers local forests and ecosystems.

Non-governmental organizations (NGOs) such as Rotary International are actively assisting homeowners in constructing more fuel-efficient and safe wood-burning stoves. One design is called the Justa stove, Just stove, Ecostove, or La EstufaJusta. Justa stoves are made out of such materials as adobe, cement, and pumice, with chimneys. Other wood-burning stoves types are also being introduced to these communities, such as rocket stoves and haybox stoves. A rocket stove is up to 30% more fuel efficient than a Justa stove, but a small portable rocket stove (for cooking) does not have a chimney and is suitable for outdoor use only. Bigger rocket stoves are connected to chimney or flue-exhaust pipe. The haybox stove is another outdoor wood-burning stove. Haybox stoves use straw, wool, or foam as an insulator, reducing fuel use by up to 70%.

4 Uses in Europe

Italy is one of the biggest markets for pellet-burning stoves in Europe, having around 30% of all homes using wood for some heat. This means about 5 million homes have a wood fuelled stove or cooker.

5 Types

- Franklin stove, originally invented by Benjamin Franklin, is a more efficient type of wood-burning fireplace. It was finicky and never caught on, but many stoves continue to be referred to as "Franklin" stoves.
- Carl Johan Cronstedt is reported to have increased efficiency of wood-burning stoves by a factor of eight in the mid-18th century.
- A Fireplace insert converts a wood-burning fireplace to a wood burning stove. A fireplace insert is a self-contained unit that sits inside the existing fireplace and chimney. They produce less smoke and require less wood than traditional fireplaces. Fireplace inserts come in different sizes for large or small homes.
- Down draft or cross draft gasification stoves, i.e. Dunsley Yorkshire, Welkom 600, Avalon Arbor wood stove, XEOOS.
- Boiler Stoves provide hot water as well as space heating. A back boiler can be an optional insert added to the back of the firebox, or a wraparound water jacket that is an integral to the stoves structure. The choice determines how much of the stoves output goes to space heating as opposed to heating water.

8. Bio diesel

Biodiesel is a liquid fuel produced from non-edible oil seeds such as Jatropha, Pongamiapinnata (Karanja), etc .which can be grown on wasteland. However, the oil extracted from these seeds has high viscosity (20 times that of diesel) which causes serious lubrication, oil contimination and injector choking problems. These problems are solved through trans-esterification, a process where the raw vegetables oils are treated with alcohol (methanol or ethanol with a catalyst) to form methyl or ethyl esters. The monoesters produced by trans-esterifying vegetable oil are called 'biodiesel' having low fuel viscosity with high octane number and heating value. Endurance tests show that biodiesel can be adopted as an alternative fuel for existing diesel engines without modifications. In EU and USA, edible vegetable oil like sunflower, groundnut, soyabean and cotton seed, etc. are used to produce biodiesel. India is endowed with a number of non-edible vegetable oil producing trees which thrives in inhospitable conditions of heat, low water, rocky and sandy soils, a renewable resource of economic significance (Jojoba in Rajasthan). Biodiesel is the name of diesel fuel made from vegetable oil or animal fats. The concept dates back to 1885, when Dr. Rudolf Diesel developed the first diesel engine to run on vegetable oil. In recent past the use of bio oil as an alternative renewable fuel to compete with petroleum was proposed during 1980. The advantages of biodiesel as engine fuel are: (i) biodegradable and produces 80% less CO2 and 100% less SO2 emissions, (ii) renewable, (iii) higher octane number, (iv) can be used as neat fuel (100% biodiesel) or mixed in any ratio with petro-diesel, and (iv) has a higher flash point making it safe to transport.

Selected fuel properties of biodiesel and petrodiesel are given in Table 1.

Table -1 Properties of biodiesel and petrodiesel		
Properties	*Petrodiesel*	*Biodiesel*
Boiling point, °C	188–343	182–338
Viscosity at 40°C	1.3–4.1	1.9–6.0
Carbon, wt%	87	77
Hydrogen, wt%	13	12
Oxygen, wt%	0	11
Sulphur, wt%	0.05 max	0.0–0.0024
Heating value, kcal/litre	7278	6491

Production of Biodiesel from Jatropha

Jatrophacurcas drought resistant perennial shrub with 4– 5 metre height is ideally suited to green up the wastelands in arid areas. Commercial seed production commences from the 6th year onwards with yield of 6000 kg/ ha under rain-fed conditions and 12000 kg/ ha in irrigated areas. The average oil production is 0.25 kg oil/ kg seed. The oil cake is used as organic fertilizer. Scientists of Central Salt & Marine Chemical Research Institute (CSMCRI) Bhavnagar (Gujarat) have confirmed the use of Jatrophacurcas and Jojoba seed oil as promising substitutes for diesel.

- The yield of Jojoba seed is 0.5 kg per plant after 10 years of plantation, Jojoba seed costs ` 200/ kg, so presently it is uneconomical as feedstock for engine oil. The characteristics of four biodiesels obtained from vegetable oils of peanut, soyabean, sunflower Jatropha and diesel are given in Table-2

Table -2 Characteristics of four biodiesels					
Name	*Flash point* (°C)	*Density at* 20/40°C	*Viscosity*	*Octane number*	*Heating value* (MJ/litre)
Diesel	32	0.82–0.86	2.0–7.5	42	34.5–36.0
Biodiesel (Jatropha)	161	0.878	4.54	65	33.7
Biodiesel (Sunflower)	183	0.880	4.60	49	33.5
Biodiesel Soyabean	178	0.885	4.50	45	33.5
Biodiesel Peanut	176	0.883	4.90	54	33.6

- The heat of combustion for biodiesel is up to 95% by volume of conventional diesel, but biodiesel being oxygenated provides the same fuel value as the diesel. The parameters in Table 1justify Jatropha seed (cost ` 5.0 /kg) as an economically favourable feedstock to produce biodiesel. Oil is extracted from Jatropha seeds in an oil press. It is treated with methanol (CH 3OH) to produce three methyl ester molecules and one glycerol molecule. Alkalis like NaOH or KOH are used to catalyze the reaction having the following constituents: 1000 litre Jatropha oil + 400 litre (CH 3OH) + 10 litre catalyst. The reaction process is completed rapidly, glycerol is separated and methyl ester is obtained as biodiesel. The Ministry of Petroleum and Natural Gas has opened a biofuel centre in Delhi to build awareness of importance of Jatrophacurcas cultivation and manufacture of biodiesel. The Indian Oil Corporation (IOC) has already established a biodiesel plant at Faridabad and another one being established in Panipat refinery to prepare 30,000 litres of biodiesel daily by crushing 100,000 kg Jatropha seeds. Biodiesel shall be blended with diesel to the extent of 5% in different Indian climatic conditions. Approximately, 40 million tonnes of HSD is consumed annually in India, thus, only 5% replacement of petroleum fuel by biodiesel would save the country approximately ` 4000 crores in foreign exchange yearly.