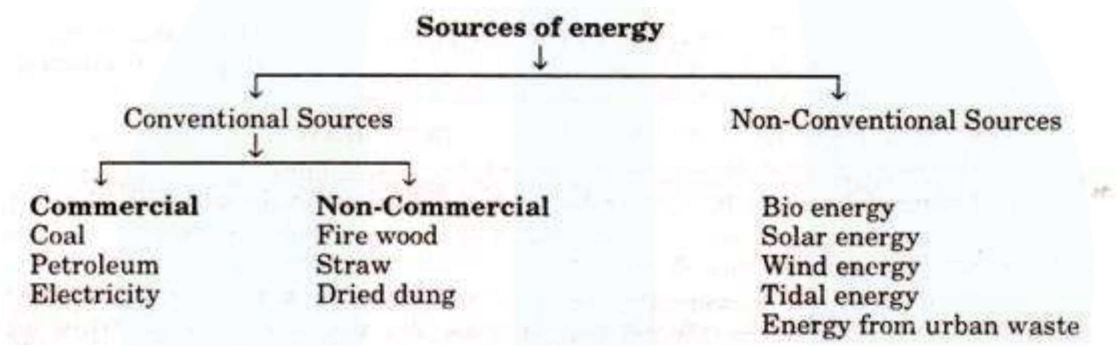
CONVENTIONAL AND NON CONVENTIONAL ENERGY

Energy is one of the most important component of economic infrastructure. It is the basic input required to sustain economic growth. There is direct relation between the level of economic development and per capita energy consumption. Simply speaking more developed a country, higher is the per capita consumption of energy and vice-versa. India's per capita consumption of energy is only one eighth of global average. This indicates that our country has low rate of per capita consumption of energy as compared to developed countries.

Two Main Sources of Energy:

The sources of energy are of following types:



1. Conventional Sources of Energy:

These sources of energy are also called non-renewable sources. These sources of energy are in limited quantity except hydro-electric power.

These are further classified as commercial energy and non-commercial energy:

Commercial Energy Sources:

These are coal, petroleum and electricity. These are called commercial energy because they have a price and consumer has to pay the price to purchase them.

(a) Coal and Lignite:

Coal is the major source of energy. Coal deposits in India are 148790 million tonnes. Total lignite reserves found at Neyveli are 3300 million tonnes. In 1950-51, annual production of coal was 32 million tonnes. In 2005-06, annual production of coal was 343 million tonnes.

Lignite production was 20.44 million tonnes in 2005-06. According to an estimate, coal reserves in India would last about 130 years. India is now the fourth largest coal producing country in the world. Coal deposits are mainly found in Orissa, Bihar, Bengal and Madhya Pradesh. It provides employment to 7 lakh workers.

(b) Oil and Natural Gas:

In these days oil is considered as the most important source of energy in India and the world. It is widely used in automobiles, trains, planes and ships etc. In India it is found in upper Assam, Mumbai High and in Gujarat. The resources of oil are small in India.

In 1950-51, the total production of oil in India was 0.3 million tonnes. It increased to 32.4 million tonnes in 2000-01. Despite tremendous increase in oil production. India still imports 70% of has oil requirements from abroad. In 1951, there was only one oil refinery in Assam.

After independence 13 such refineries were set up in public sector and their refining capacity was 604 lakh tonnes. After implementation of economic reforms, private refineries are also engaged in oil refining. As per current rate of consumption, oil reserves in India may last about 20 to 25 years.

Natural gas has been the most important source of energy since last two decades. It can be produced in two ways:

(i) With petroleum products as associated gas.

(ii) Free gas obtained from gas fields in Assam, Gujarat and Andhra Pradesh.

It is used in fertilizer and petro-chemical plants and gas based thermal power plants. Total production of natural gas was 31.96 billion cubic metre in 2003-04.

(c) Electricity:

Electricity is the common and popular source of energy. It is used in commercial and domestic purposes. It is used for lighting, cooking, air conditioning and working of electrical appliances like T.V., fridge and washing machine.

In 2000-01 agriculture sector consumed 26.8%, industrial sector 34.6% and 24% of electricity was used for domestic purposes and 7% was used for commercial purpose. Railways consumed 2.6% and miscellaneous consumption was 5.6%.

There are three main sources of power generation:

1. Thermal Power

2. Hydro-electric power

3. Nuclear Power

1**. Thermal Power:**

It is generated in India at various power stations with the help of coal and oil. It has been a major source of electric power. In 2004-05, its share in total installed capacity was 70 percent.

2. Hydroelectric Power:

It is produced by constructing dams over overflowing rivers. For example Bhakra Nangal Project, Damodor Valley Project and Hirakund Project etc. In 1950-51, installed capacity of hydro-electricity was 587.4 MW and in 2004-05, it was 19600 MW.

3. Nuclear Power:

India has also developed nuclear power. Nuclear Power plants use uranium as fuel. This fuel is cheaper than coal. India has nuclear power plants at Tarapur, Kota (Rajasthan) Kalapakam (Chennai) Naroura (UP). Its supply accounts for only 3 percent of the total installed capacity.

Non-Commercial energy Sources:

These sources include fuel wood, straw and dried dung. These are commonly used in rural India. According to an estimate, the total availability of fuel wood in India was only 50 million tonnes a year. It is less than 50% of the total requirements. In coming years, there would be shortage of fire wood.

Agricultural wastes like straw are used as fuel for cooking purposes. According to one estimate agricultural waste used for fuel might be 65 million tonnes. Animal dung when dried is also used for cooking purposes. Total animal dung production is 324 million tonnes out of which 73 million tonnes are used as fuel for cooking purposes. The straw and dung can be used as valuable organic manure for increasing fertility of soil and in turn productivity.

2. NON-CONVENTIONAL SOURCES OF ENERGY:

Besides conventional sources of energy there are non-conventional sources of energy. These are also called renewable sources of energy. Examples are Bio energy, solar energy, wind energy and tidal energy. Govt. of India has established a separate department under the Ministry of Energy called as the Department of Non-conventional Energy Sources for effective exploitation of non-conventional energy.

The various sources are given below:

1. Solar Energy:

Energy produced through the sunlight is called solar energy. Under this programme, solar photovoltaic cells are exposed to sunlight and in the form of electricity is produced. Photovoltaic cells are those which convert sun light energy into electricity. In year 1999-2000, 975 villages were illuminated through solar energy. Under Solar Thermal Programme, solar energy is directly obtained. Sunlight is converted into thermal power. Solar energy is used for cooking, hot water and distillation of water etc.

2. Wind Energy:

This type of energy can be produced by harnessing wind power. It is used for operating water pumps for irrigation purposes. Approximately 2756 wind pumps were set up for this purpose. In seven states, wind power operated power houses were installed and their installed capacity was 1000 MW. India has second position in wind power energy generation.

3. Tidal Energy:

Energy produced by exploiting the tidal waves of the sea is called tidal energy. Due to the absence of cost effective technology, this source has not yet been tapped.

4. Bio Energy:

This type of energy is obtained from organic matter.

It is of two kinds:

(i) Bio Gas:

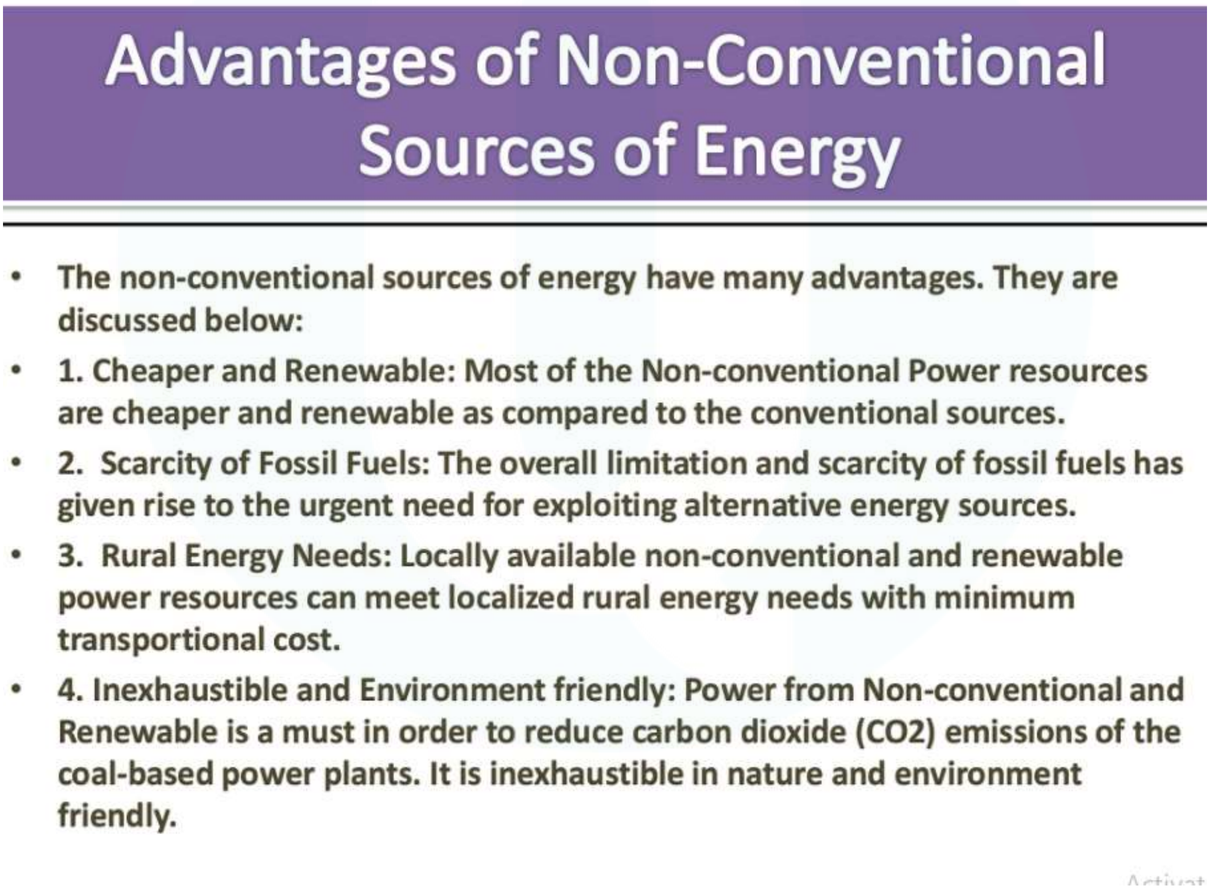
Bio Gas is obtained from Gobar Gas Plant by putting cow dung into the plant. Besides producing gas this plant converts gobar into manure. It can be used for cooking, lighting and generation of electricity. 26.5 lakh bio gas plants had been established by the year 2003-04. They produce more than 225 lakh tonnes of manure. About 1828 large community bio gas plants have been established in the country.

(ii) Bio Mass:

It is also of a source of producing energy through plants and trees. The purpose of bio mass programme is to encourage afforestation for energy. So that fuel for the generation of energy based on gas technique and fodder for the cattle could be obtained, 56 MW capacity for the generation of bio mass energy has been installed.

5. Energy from Urban Waste:

Urban waste poses a big problem for its disposal. Now it can be used for generation of power. In Timarpur (Delhi) a power Ration of 3.75 capacity has been set up to generate energy from the garbage.



SOLAR ENERGY

The Earth receives around 170,000 terawatts of solar energy continuously, which is roughly 10,000 times what is needed to power the world. Every day, the sun radiates an enormous amount of energy. This energy comes from within the sun itself. Like most stars, the sun is a big gas ball made mostly of hydrogen and helium. The sun produces energy in a process called nuclear fusion. The high pressure and temperature in the sun‟s core cause hydrogen atoms to split apart. Four hydrogen nuclei combine or fuse, to form one helium atom, producing radiant energy in the process.

The sun radiates more energy in one second than the world has used since time began. Only a small portion of this energy strikes the earth, one part in two billion. Yet this amount of energy is enough to meet the world‟s needs, if it could be harnessed. About 15 percent of the radiant energy that reaches the earth is reflected back into space. Another 30 percent is used to evaporate water, which is lifted into the atmosphere and produces rainfall. The radiant energy is also absorbed by plants, landmasses and the oceans.

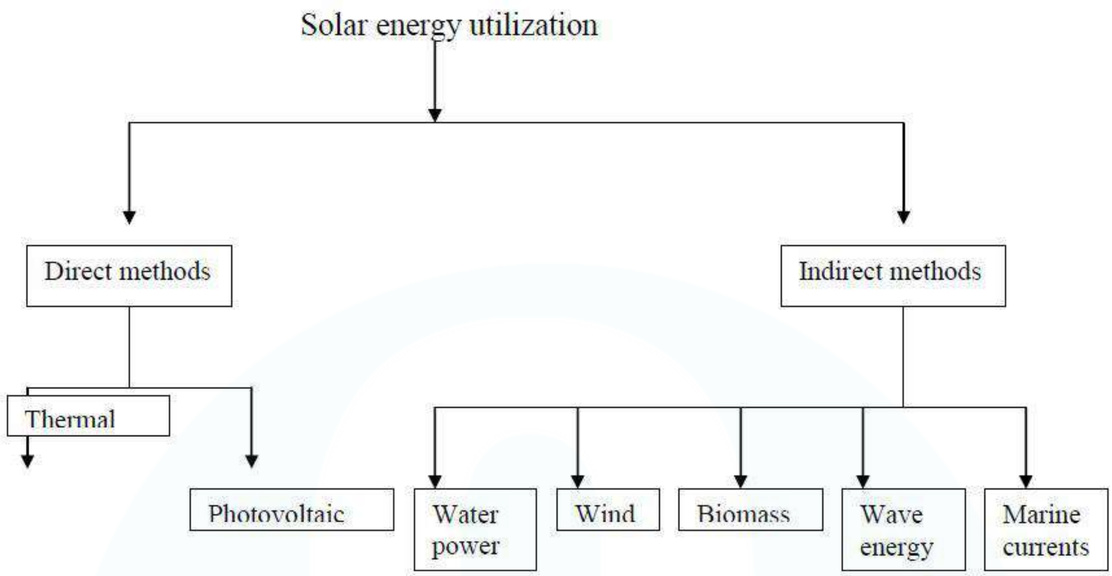
Solar energy is a very large, inexhaustible source of energy. The power from the sun intercepted by the earth is approximtely1.8×1011 MW which is many thousand times larger than the present consumption rate on the earth of all commercial energy sources. Thus, in principle, solar energy could supply all the present and future energy needs of the world on a continuing basis. This makes it one of the most promising of the unconventional energy sources. The advantages of solar energy are (i) environmentally clean source of energy and (ii) freely available in adequate quantities in almost all parts of the world where people live. The main problems associated with solar energy are: (i) dilute source of energy and (ii) availability varies widely with time. India, being tropical country receives solar insolation in the order of 1650-2100 kwh/m2/year for nearly 250-300 days. Solar energy can be used directly or indirectly.

Applications of solar energy

- Heating and Cooling of buildings
- Solar water and air heating
- Salt production by evaporation of seawater
- Solar distillation
- Solar drying of agricultural products
- Solar cookers
- Solar water pumping
- Solar refrigeration
- Electricity generation through Photo voltaic cells
- Solar furnaces
- Industrial process heat

- Solar thermal power generation

Classification of methods for solar energy utilization



Photovoltaic cells

Photovoltaic solar cells are thin silicon disks that convert sunlight into electricity. These disks act as energy sources for a wide variety of uses, including: calculators and other small devices; telecommunications; rooftop panels on individual houses; and for lighting, pumping, and medical refrigeration for villages in developing countries. Solar cells in the form of large arrays are used to power satellites and, in rare cases, to provide electricity for power plants.

When research into electricity began and simple batteries were being made and studied, research into solar electricity followed amazingly quickly. As early as 1839, Antoine-Cesar Becquerel exposed a chemical battery to the sun to see it produce voltage. This first conversion of sunlight to electricity was one percent efficient. That is, one percent of the incoming sunlight was converted into electricity. Willoughby Smith in 1873 discovered that selenium was sensitive to light; in 1877 Adams and Day noted that selenium, when exposed to light, produced an electrical current. Charles Fritts, in the 1880s, also used gold-coated selenium to make the first solar cell, again only one percent efficient. Nevertheless, Fritts considered his cells to be revolutionary. He envisioned free solar energy to be a means of decentralization, predicting that solar cells would replace power plants with individually powered residences.

With Albert Einstein's explanation in 1905 of the photoelectric effect—metal absorbs energy from light and will retain that energy until too much light hits it—hope soared anew that solar electricity at higher efficiencies would become feasible. Little progress was made, however, until research into diodes and transistors yielded the knowledge necessary for Bell scientists Gordon Pearson, Darryl Chapin, and Cal Fuller to produce a silicon solar cell of four percent efficiency in 1954.

Further work brought the cell's efficiency up to 15 percent. Solar cells were first used in the where it was used successfully for many years.

A type of solar cell to fully meet domestic energy needs has not as yet been developed, but solar cells have become successful in providing energy for artificial satellites. Fuel systems and regular batteries were too heavy in a program where every ounce mattered. Solar cells provide more energy per ounce of weight than all other conventional energy sources, and they are cost-effective.

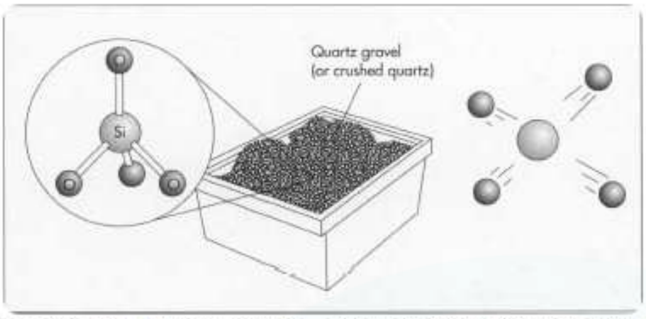
Only a few large scale photovoltaic power systems have been set up. Most efforts lean toward providing solar cell technology to remote places that have no other means of sophisticated power. About 50 megawatts are installed each year, yet solar cells provide only about. 1 percent of all electricity now being produced. Supporters of solar energy claim that the amount of solar radiation reaching the Earth's surface each year could easily provide all our energy needs several times over, yet solar cells have a long way to go before they fulfill Charles Fritts's dream of free, fully accessible solar electricity.

Components

The basic component of a solar cell is pure silicon, which is not pure in its natural state.

Pure silicon is derived from such silicon dioxides as quartzite gravel (the purest silica) or crushed quartz. The resulting pure silicon is then doped (treated with) with phosphorous and boron to produce an excess of electrons and a deficiency of electrons respectively to make a semiconductor capable of conducting electricity. The silicon disks are shiny and require an anti-reflective coating, usually titanium dioxide.

The solar module consists of the silicon semiconductor surrounded by protective material in a metal frame. The protective material consists of an encapsulant of transparent silicon rubber or butyryl plastic (commonly used in **automobile windshields)** bonded around the cells, which are then embedded in ethylene vinyl acetate. A polyester film (such as mylar or tedlar) makes up the backing. A glass cover is found on terrestrial arrays, a lightweight plastic cover on satellite arrays. The electronic parts are standard and consist mostly of copper. The frame is either steel or aluminum. Silicon is used as the cement to put it all together.



To make solar cells, the raw materials—silicon dioxide of either quartzite gravel or crushed quartz—are first placed into an electric arc furnace, where a carbon arc is applied to release the oxygen. The products are carbon dioxide and molten silicon. At this point, the silicon is still not pure enough to be used for solor cells and requires further purification.

Manufacturing Process

1. **Purifying the silicon**

a. The silicon dioxide of either quartzite gravel or crushed quartz is placed into an electric arc furnace. A carbon arc is then applied to release the oxygen. The products are carbon dioxide and molten silicon. This simple process yields silicon with one percent impurity, useful in many industries but not the solar cell industry.

b. The 99 percent pure silicon is purified even further using the floating zone technique. A rod of impure silicon is passed through a heated zone several times in the same direction. This procedure "drags" the impurities toward one end with each pass. At a specific point, the silicon is deemed pure, and the impure end is removed.

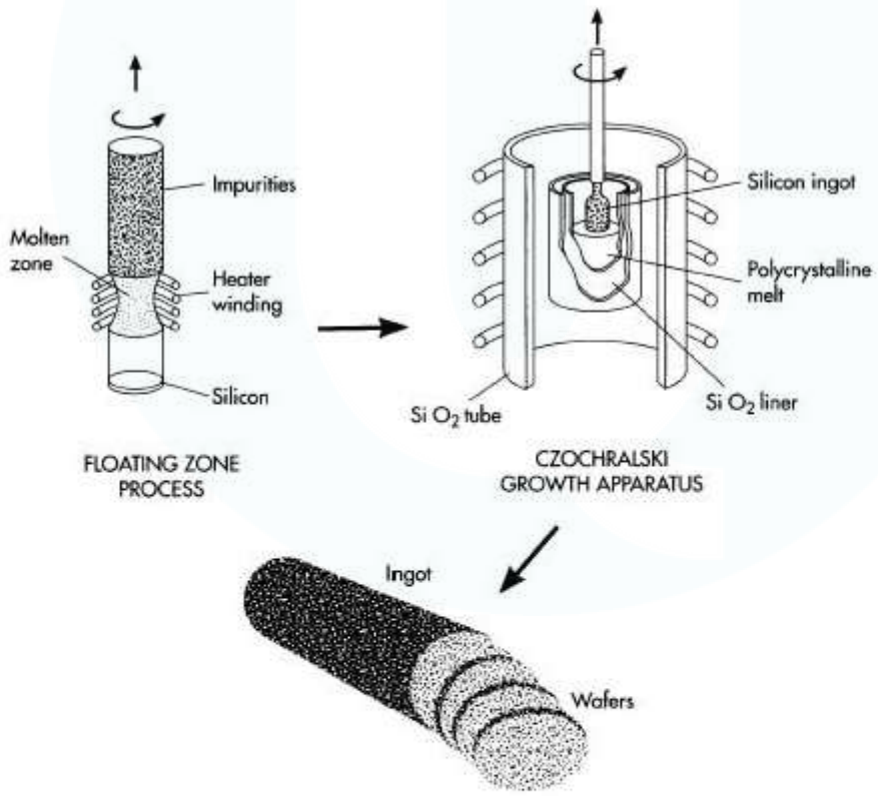
2. **Making single crystal silicon**

c. Solar cells are made from silicon boules, polycrystalline structures that have the atomic structure of a single crystal. The most commonly used process for creating the boule is called the Czochralski method. In this process, a seed crystal of silicon is dipped into melted polycrystalline silicon. As the seed crystal is withdrawn and rotated, a cylindrical ingot or "boule" of silicon is formed. The ingot withdrawn is unusually pure, because impurities tend to remain in the liquid.

3. **Making silicon wafers**

d. From the boule, silicon wafers are sliced one at a time using a circular saw whose inner diameter cuts into the rod, or many at once with a multi wire saw. (A diamond saw produces cuts that are as wide as the wafer millimetre thick.) Only about one-half of the silicon is lost from the boule to the finished circular wafer—more if the wafer is then cut to be rectangular or hexagonal. Rectangular or hexagonal wafers are sometimes used in solar cells because they can be fitted together perfectly, thereby utilizing all available space on the front surface of the solar cell.

e. The wafers are then polished to remove saw marks. (It has recently been found that rougher cells absorb light more effectively, therefore some manufacturers have chosen not to polish the wafer.)



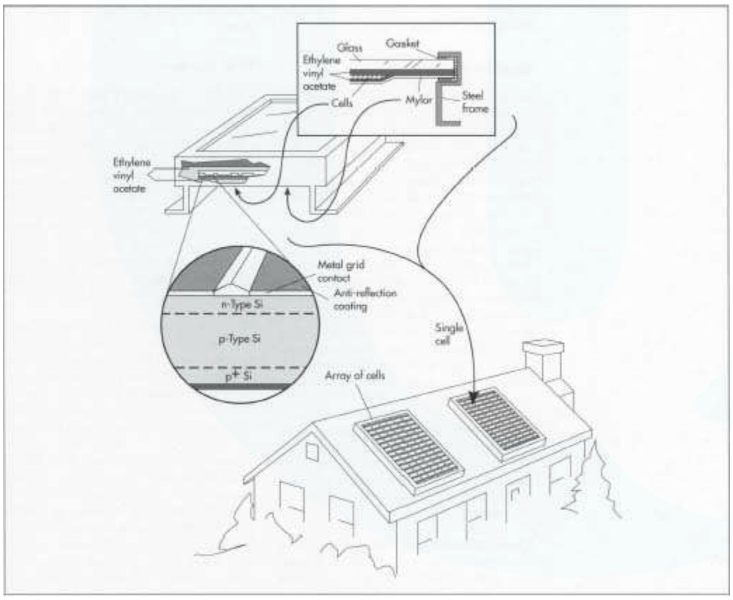
Doping

f. The traditional way of doping (adding impurities to) silicon wafers with boron and phosphorous is to introduce a small amount of boron during the Czochralski process in step “c” above. The wafers are then sealed back to back and placed in a furnace to be heated to slightly below the melting point of silicon (2,570 degrees Fahrenheit or 1,410 degrees Celsius) in the presence of phosphorous gas. The phosphorous atoms "burrow" into the silicon, which is more porous because it is close to becoming a liquid. The temperature and time given to the process is carefully controlled to ensure a uniform junction of proper depth.

A more recent way of doping silicon with phosphorous is to use a small particle accelerator to shoot phosphorous ions into the ingot. By controlling the speed of the ions, it is possible to control their penetrating depth. This new process, however, has generally not been accepted by commercial manufacturers.

Placing electrical contacts

g. Electrical contacts connect each solar cell to another and to the receiver of produced current. The contacts must be very thin (at least in the front) so as not to block sunlight to the cell. Metals such as palladium/silver, nickel, or copper are vacuum-evaporated



This illustration shows the makeup of a typical solar cell. The cells are encapsulated in ethylene vinyl acetate and placed in a metal frame that has a mylar back sheet and glass cover.

Through a photoresist, silkscreened, or merely deposited on the exposed portion of cells that have been partially covered with wax. All three methods involve a system in which the part of the cell on which a contact is not desired is protected, while the rest of the cell is exposed to the metal.

h. After the contacts are in place, thin strips ("fingers") are placed between cells. The most commonly used strips are tin-coated copper.

The anti-reflective coating

i. Because pure silicon is shiny, it can reflect up to 35 percent of the sunlight. To reduce the amount of sunlight lost, an anti-reflective coating is put on the silicon wafer. The most commonly used coatings are titanium dioxide and silicon oxide, though others are used. The material used for coating is either heated until its molecules boil off and travel to the silicon and condense, or the material undergoes sputtering. In this process, a high voltage knocks molecules off the material and deposits them onto the silicon at the opposite electrode. Yet another method is to allow the silicon itself to react with oxygen- or nitrogen-containing gases to form silicon dioxide or silicon nitride. Commercial solar cell manufacturers use silicon nitride.

Encapsulating the cell

j. The finished solar cells are then encapsulated; that is, sealed into silicon rubber or ethylene vinyl acetate. The encapsulated solar cells are then placed into an aluminum frame that has a mylar or tedlar back sheet and a glass or plastic cover.

BIOFUEL

It is a generic description given to all type of fuel produced from biomass, that is, material derived from recently living organisms. This is the scientific name given to any plant or animal substance that is combustible, thus releasing off energy which can be then used for a number of purposes, including for producing motion (such as the movement of a piston in an internal combustion engine) and heating liquids (such as water in a boiler).

Types of biofuels

Biofuels can range from solid, liquid and gaseous products, and their application is as varied as that of the petroleum products they replace. Biofuels can be used in almost all applications where petroleum products are used. Only in the aviation industry is their used still very limited, almost inexistent, however recent studies and experimental flights might in the future lead to a breakthrough and a wider use similar to that experienced in the road transport sector. The following is a list of the main biofuels available and a brief description of their use.

1. Solid biofuels

Examples of solid biofuels are probably the most common to understand as their use has been present for as long as man has discovered fire. The main examples charcoal which are used for everyday use in heating and cooking.

Liquid biofuels

Liquid biofuels Liquid biofuels, as their name suggests, are fuels derived from biomass and processed to produce a combustible liquid fuel.

There are two main categories:

a) Alcohol fuels - these include ethanol and methanol
b) Vegetable oils - derived from plant seeds, such as sunflower, sesame, linseed

2. Bioethanol

Ethanol fuels basically an alcohol fuel produced by the use of enzymes and micro-organisms through the process of fermentation of starches and sugar. It can be used as a fuel, mainly as a biofuel alternative to petrol, and is widely used in cars in Brazil, where sugar cane is used as the base material. Ethanol with less than 1% water called anhydrous ethanol can be blended with petrol in varying quantities. Currently, all spark ignited petrol engines can operate with mixtures of up to 5% bioethanol (E5), however certain engine manufacturers do not discourage and actually suggest higher blends of bioethanol to be used.

The substitution of ethanol for gasoline in passenger cars and light vehicles in Brazil is one of the largest biomass-to-energy programmes in existence today. Engines that run strictly on gasoline are no longer available in the country, having been replaced by neat ethanol engines and by gasohol engines that burn a mixture of 78 per cent gasoline and 22 per cent ethanol by volume. Technological advances, including more efficient production and processing of sugarcane, are responsible for the availability and low price of ethanol. The transition to ethanol fuel has reduced Brazil‟s dependence on foreign oil (thus lowering its import export ratio), created significant employment opportunities and greatly enhanced urban air quality. In addition, because sugarcane-derived ethanol is a renewable resource (the cane is replanted at the same rate it is harvested), the combustion of ethanol adds virtually no net carbon dioxide to the atmosphere and so helps reduce the threat of global warming.

3. Methanol

Itis produced by a process of chemical conversion. It can be produced from any biomass with moisture content of less than 60%; potential feed stocks include forest and agricultural residues, wood and various energy crops. As with ethanol it can either be blended with gasoline to improve the octane rating of the fuel or used in its neat form. Both ethanol and methanol are often preferred fuels for racing cars.

4. Vegetable oils

A further method of extracting energy from biomass is the production of vegetable oils as a fuel known as biodiesel. The process of oil extraction is carried out the same way as for extraction of edible oil from plants. There are many crops grown in rural areas of the developing world which are suitable for oil production – sunflower, coconut, cotton seed, palm, rapeseed, soy bean, peanut, hemp and more. Sunflower oil, for example, has an energy content about 85% that of diesel fuel.

There are two well-established technologies for oil extraction:

- The simple screw press, which is a device for physically extracting the oil from the plant - this technology is well suited to small-scale production of oil as fuel or as foodstuff in rural areas. The press can be motorised or hand-operated.

- Solvent extraction is a chemical process which requires large, sophisticated equipment. This method is more efficient - that is, it extracts a greater percentage of the oil from the plant - but is less suited to rural applications. The oil, as well as being used for lighting and heating, can be used as a fuel in internal combustion engines. Biodiesel production is not complex and can be done on a small scale. The vegetable oil is converted to a useable fuel by adding ethanol or methanol alcohol along with a catalyst to improve the reaction. Small amounts of potassium hydroxide or sodium hydroxide (commonly called lye or caustic soda, which is used in soap making) are used as the catalyst material. Glycerine separates out as the reaction takes place and sinks to the bottom of the container. This removes the component that gums up the engine so that a standard diesel engine can be used. The glycerine can be used as a degreasing soap or refined to make other products.

5. Gaseous biofuels

Biogas is a renewable fuel, which is produced by the breaking down of organic matter by a process of microbiological activity. Basically this means that rotting municipal waste, food waste or sewage (both human and animal) is turned into gas by means of „anaerobic conversion" in a digester.Biogas contains methane, which in itself is a fuel and can be recovered from industrial anaerobic digesters, mechanical biological treatment systems and engineered landfills. In engineered landfills, the collected landfill gas can be used to produce electricity and heat.

FUEL CELLS

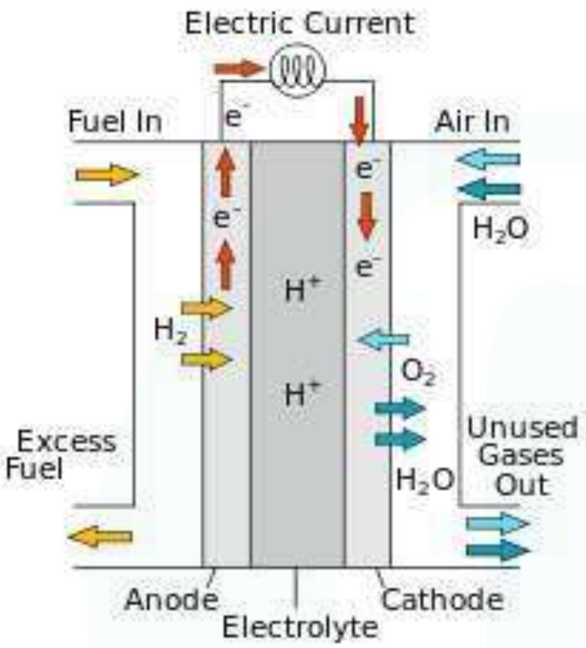
A fuel cell uses the chemical energy of hydrogen or another fuel to cleanly and efficiently produce electricity. If hydrogen is the fuel, electricity, water, and heat are the only products. Fuel cells are unique in terms of the variety of their potential applications; they can provide power for systems as large as a utility power station and as small as a laptop computer.

Why Study Fuel Cells

Fuel cells can be used in a wide range of applications, including transportation, material handling, stationary, portable, and emergency backup power applications. Fuel cells have several benefits over conventional combustion-based technologies currently used in many power plants and passenger vehicles. Fuel cells can operate at higher efficiencies than combustion engines, and can convert the chemical energy in the fuel to electrical energy with efficiencies of up to 60%. Fuel cells have lower emissions than combustion engines. Hydrogen fuel cells emit only water, so there are no carbon dioxide emissions and no air pollutants that create smog and cause health problems at the point of operation. Also, fuel cells are quiet during operation as they have fewer moving parts.

How Fuel Cells Work

Fuel cells work like batteries, but they do not run down or need recharging. They produce electricity and heat as long as fuel is supplied. A fuel cell consists of two electrodes—a negative electrode (or anode) and a positive electrode (or cathode)—sandwiched around an electrolyte. A fuel, such as hydrogen, is fed to the anode, and air is fed to the cathode. In a hydrogen fuel cell, a catalyst at the anode separates hydrogen molecules into protons and electrons, which take different paths to the cathode. The electrons go through an external circuit, creating a flow of electricity. The protons migrate through the electrolyte to the cathode, where they unite with oxygen and the electrons to produce water and heat.



Types of Fuel Cells

Fuel cells are classified primarily by the kind of electrolyte they employ. This classification determines the kind of electro-chemical reactions that take place in the cell, the kind of catalysts required, the temperature range in which the cell operates, the fuel required, and other factors. These characteristics, in turn, affect the applications for which these cells are most suitable. There are several types of fuel cells currently under development, each with its own advantages, limitations, and potential applications. Learn more about the following types of fuel cells.

Polymer electrolyte membrane fuel cells

Polymer electrolyte membrane (PEM) fuel cells—also called proton exchange membrane fuel cells—deliver high power density and offer the advantages of low weight and volume compared with other fuel cells. PEM fuel cells use a solid polymer as an electrolyte and porous carbon electrodes containing a platinum or platinum alloy catalyst. They need only hydrogen, oxygen from the air, and water to operate. They are typically fueled with pure hydrogen supplied from storage tanks or reformers.

PEM fuel cells operate at relatively low temperatures, around 80°C (176°F). Low-temperature operation allows them to start quickly (less warm-up time) and results in less wear on system components, resulting in better durability. However, it requires that a noble-metal catalyst (typically platinum) be used to separate the hydrogen's electrons and protons, adding to system cost. The platinum catalyst is also extremely sensitive to carbon monoxide poisoning, making it necessary to employ an additional reactor to reduce carbon monoxide in the fuel gas if the hydrogen is derived from a hydrocarbon fuel. This reactor also adds cost.

PEM fuel cells are used primarily for transportation applications and some stationary applications. Due to their fast startup time and favorable power-to-weight ratio, PEM fuel cells are particularly suitable for use in passenger vehicles, such as cars and buses.

Direct methanol fuel cells

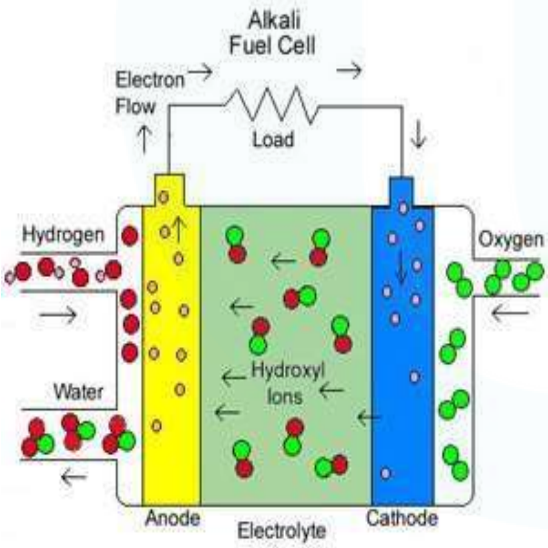
Most fuel cells are powered by hydrogen, which can be fed to the fuel cell system directly or can be generated within the fuel cell system by reforming hydrogen-rich fuels such as methanol, ethanol, and hydrocarbon fuels. Direct methanol fuel cells (DMFCs), however, are powered by pure methanol, which is usually mixed with water and fed directly to the fuel cell anode.

Direct methanol fuel cells do not have many of the fuel storage problems typical of some fuel cell systems because methanol has a higher energy density than hydrogen—though less than gasoline or diesel fuel. Methanol is also easier to transport and supply to the public using our current infrastructure because it is a liquid, like gasoline. DMFCs are often used to provide power for portable fuel cell applications such as cell phones or laptop computers.

Alkaline fuel cells

Alkaline fuel cells (AFCs) were one of the first fuel cell technologies developed, and they were the first type widely used in the U.S. space program to produce electrical energy and water on-board spacecraft. These fuel cells use a solution of potassium hydroxide in water as the electrolyte and can use a variety of non-precious metals as a catalyst at the anode and cathode. In recent years, novel AFCs that use a polymer membrane as the electrolyte have been developed. These fuel cells are closely related to conventional PEM fuel cells, except that they use an alkaline membrane instead of an acid membrane. The high performance of AFCs is due to the rate at which electro-chemical reactions take place in the cell. They have also demonstrated efficiencies above 60% in space applications.

A key challenge for this fuel cell type is that it is susceptible to poisoning by carbon dioxide (CO_2). In fact, even the small amount of CO_2 in the air can dramatically affect cell performance and durability due to carbonate formation. Alkaline cells with liquid electrolytes can be run in a recirculating mode, which allows for electrolyte regeneration to help reduce the effects of carbonate formation in the electrolyte, but the recirculating mode introduces issues with shunt currents. The liquid electrolyte systems also suffer from additional concerns including wettability, increased corrosion, and difficulties handling differential pressures. Alkaline membrane fuel cells (AMFCs) address these concerns and have lower susceptibility to CO_2 poisoning than liquid-electrolyte AFCs do. However, CO_2 still affects performance, and performance and durability of the AMFCs still lag that of PEMFCs. AMFCs are being considered for applications in the W to kW scale. Challenges for AMFCs include tolerance to carbon dioxide, membrane conductivity and durability, higher temperature operation, water management, power density, and anode electrocatalysis.

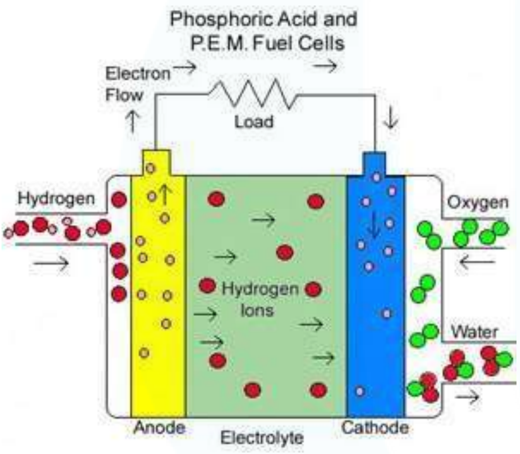


Phosphoric acid fuel cells

Phosphoric acid fuel cells (PAFCs) use liquid phosphoric acid as an electrolyte—the acid is contained in a Teflon-bonded silicon carbide matrix—and porous carbon electrodes containing a platinum catalyst.

The PAFC is considered the "first generation" of modern fuel cells. It is one of the most mature cell types and the first to be used commercially. This type of fuel cell is typically used for stationary power generation, but some PAFCs have been used to power large vehicles such as city buses.

PAFCs are more tolerant of impurities in fossil fuels that have been reformed into hydrogen than PEM cells, which are easily "poisoned" by carbon monoxide because carbon monoxide binds to the platinum catalyst at the anode, decreasing the fuel cell's efficiency. PAFCs are more than 85% efficient when used for the co-generation of electricity and heat but they are less efficient at generating electricity alone (37%–42%). PAFC efficiency is only slightly more than that of combustion-based power plants, which typically operate at around 33% efficiency. PAFCs are also less powerful than other fuel cells, given the same weight and volume. As a result, these fuel cells are typically large and heavy. PAFCs are also expensive. They require much higher loadings of expensive platinum catalyst than other types of fuel cells do, which raises the cost.



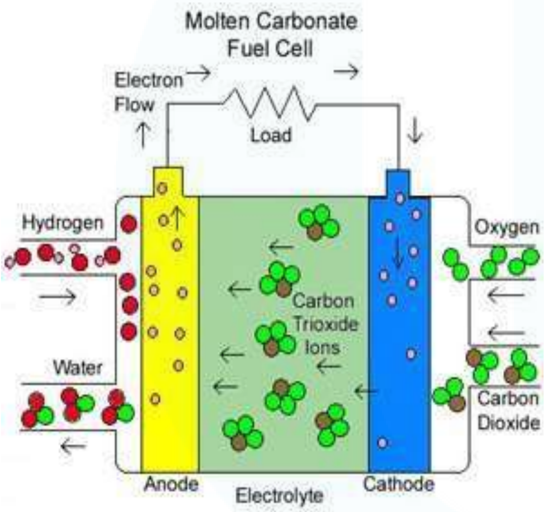
Molten carbonate fuel cells

Molten carbonate fuel cells (MCFCs) are currently being developed for natural gas and coal-based power plants for electrical utility, industrial, and military applications. MCFCs are high-temperature fuel cells that use an electrolyte composed of a molten carbonate salt mixture suspended in a porous, chemically inert ceramic lithium aluminum oxide matrix. Because they operate at high temperatures of 650°C (roughly 1,200°F), non-precious metals can be used as catalysts at the anode and cathode, reducing costs.

Improved efficiency is another reason MCFCs offer significant cost reductions over phosphoric acid fuel cells. Molten carbonate fuel cells, when coupled with a turbine, can reach efficiencies approaching 65%, considerably higher than the 37%–42% efficiencies of a phosphoric acid fuel cell plant. When the waste heat is captured and used, overall fuel efficiencies can be over 85%.

Unlike alkaline, phosphoric acid, and PEM fuel cells, MCFCs do not require an external reformer to convert fuels such as natural gas and biogas to hydrogen. At the high temperatures at which MCFCs operate, methane and other light hydrocarbons in these fuels are converted to hydrogen within the fuel cell itself by a process called internal reforming, which also reduces cost.

The primary disadvantage of current MCFC technology is durability. The high temperatures at which these cells operate and the corrosive electrolyte used accelerate component breakdown and corrosion, decreasing cell life. Scientists are currently exploring corrosion-resistant materials for components as well as fuel cell designs that double cell life from the current 40,000 hours (~5 years) without decreasing performance.



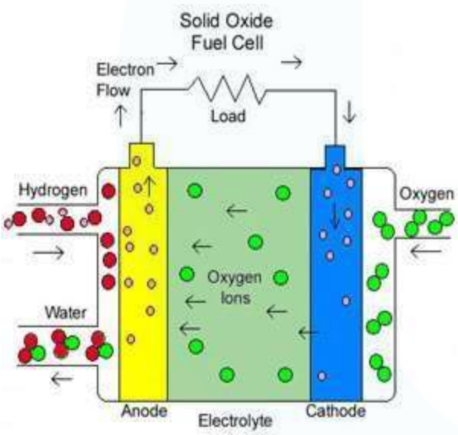
Solid oxide fuel cells

Solid oxide fuel cells (SOFCs) use a hard, non-porous ceramic compound as the electrolyte. SOFCs are around 60% efficient at converting fuel to electricity. In applications designed to capture and utilize the system's waste heat (co-generation), overall fuel use efficiencies could top 85%.

SOFCs operate at very high temperatures—as high as 1,000°C (1,830°F). High-temperature operation removes the need for precious-metal catalyst, thereby reducing cost. It also allows SOFCs to reform fuels internally, which enables the use of a variety of fuels and reduces the cost associated with adding a reformer to the system.

SOFCs are also the most sulfur-resistant fuel cell type; they can tolerate several orders of magnitude more sulfur than other cell types can. In addition, they are not poisoned by carbon monoxide, which can even be used as fuel. This property allows SOFCs to use natural gas, biogas, and gases made from coal. High-temperature operation has disadvantages. It results in a slow startup and requires significant thermal shielding to retain heat and protect personnel, which may be acceptable for utility applications but not for transportation. The high operating temperatures also place stringent durability requirements on materials. The development of low-cost materials with high durability at cell operating temperatures is the key technical challenge facing this technology.

Scientists are currently exploring the potential for developing lower-temperature SOFCs operating at or below 700°C that have fewer durability problems and cost less. Lower-temperature SOFCs have not yet matched the performance of the higher temperature systems, however, and stack materials that will function in this lower temperature range are still under development.



Reversible fuel cells

Reversible fuel cells produce electricity from hydrogen and oxygen and generate heat and water as by products, just like other fuel cells. However, reversible fuel cell systems can also use electricity from solar power, wind power, or other sources to split water into oxygen and hydrogen fuel through a process called electrolysis. Reversible fuel cells can provide power when needed, but during times of high power production from other technologies (such as when high winds lead to an excess of available wind power), reversible fuel cells can store the excess energy in the form of hydrogen. This energy storage capability could be a key enabler for intermittent renewable energy technologies.

COMPARISON FUEL CELL

Comparison of Fuel Cell Technologies

Fuel Cell Type	Common Electrolyte	Operating Temperature	Typical Stack Size	Efficiency	Applications	Advantages	Disadvantages
Polymer Electrolyte Membrane (PEM)	Perfluoro sulfonic acid	50-100°C 122-212° typically 80°C	<1kW-100kW	60% transportation 35% stationary	• Backup power • Portable power • Distributed generation • Transporation • Specialty vehicles	• Solid electrolyte reduces corrosion & electrolyte management problems • Low temperature • Quick start-up	• Expensive catalysts • Sensitive to fuel impurities • Low temperature waste heat
Alkaline (AFC)	Aqueous solution of potassium hydroxide soaked in a matrix	90-100°C 194-212°F	10-100 kW	60%	• Military • Space	• Cathode reaction faster in alkaline electrolyte, leads to high performance • Low cost components	• Sensitive to CO_2 in fuel and air • Electrolyte management
Phosphoric Acid (PAFC)	Phosphoric acid soaked in a matrix	150-200°C 302-392°F	400 kW 100 kW module	40%	• Distributed generation	• Higher temperature enables CHP • Increased tolerance to fuel impurities	• Pt catalyst • Long start up time • Low current and power
Molten Carbonate (MCFC)	Solution of lithium, sodium, and/or potassium carbonates, soaked in a matrix	600-700°C 1112-1292°F	300 kW-3 MW 300 kW module	45-50%	• Electric utility • Distributed generation	• High efficiency • Fuel flexibility • Can use a variety of catalysts • Suitable for CHP	• High temperature corrosion and breakdown of cell components • Long start up time • Low power density
Solid Oxide (SOFC)	Yttria stabilized zirconia	700-1000°C 1202-1832°F	1 kW-2 MW	60%	• Auxiliary power • Electric utility • Distributed generation	• High efficiency • Fuel flexibility • Can use a variety of catalysts • Solid electrolyte • Suitable for CHP & CHHP • Hybrid/GT cycle	• High temperature corrosion and breakdown of cell components • High temperature operation requires long start up time and limits

APPLICATIONS OF FUEL CELLS

- The first commercial use of fuel cell was in NASA space program to generate power for satellites and space capsules.

- Fuels are used for primary and backup power for commercial, industrial and residential buildings in remote and inaccessible area.
- They are used to power fuel cell vehicles including automobiles, aeroplanes, boats and submarines.

ADVANTAGES OF FUEL CELLS

1. High efficiency of energy conversion (approaching 70%) from chemical energy to electrical energy.
2. Low noise pollution & low thermal pollution.
3. Fuel cell power can reduce expensive transmission lines & minimize transmission loses for a disturbed system.
4. Fuel cells gives excellent method for efficient use of fossil fuels hence saves fossil fuels.
5. Fuel cells are less polluting. The chemical process involved in it is clean. It does not produce polluting exhaust. Mostly the by-products are water & waste heat, which are environmentally acceptable when hydrogen & air are used as reactants.
6. In case of fossil fuels, when used as reagents, environmentally undesirable NO_x are produced since there is no combustion in the process.
7. Hydrogen-Oxygen fuel cells produce drinking water of potable quality.
8. Designing is modular, therefore the parts are exchangeable.
9. Low maintenance cost.
10. Fuel cell performance is independent of power plant size. The efficiency does not depend on the size of power plant. It remains same for the plants of MW or kW or W size.
11. Fast start up time for low temperature system.
12. The heat is cogenerated hence increases efficiency of high
13. Temperature system.
14. The demand for variations in power & energy densities is easily met as required. E.g. Laptop, computers requires low power density & high energy density whereas

automobile requires high power density, high energy density. Both can be powered by fuel cells.

15. Fuel cells automotive batteries can render electric vehicles, efficient & refillable.

DISADVANTAGES OF FUEL CELLS

1. High initial cost.
2. Life times of the cells are not accurately known.
3. Large weight and volume of gas fuel storage system.
4. High cost of pure hydrogen.
5. Hydrogen can be stored in lesser volume by liquefaction but liquefaction itself require 30% of the stored energy.
6. Lack of infrastructure for distributing hydrogen.