ME8792-POWER PLANT ENGINEERING

UNIT IV- POWERFROMRENEWABLEENERGY

4.5-GEO THERMAL, BIOGAS AND FUEL CELL POWERSYSTEMS.

GEOTHERMALPOWERPLANT

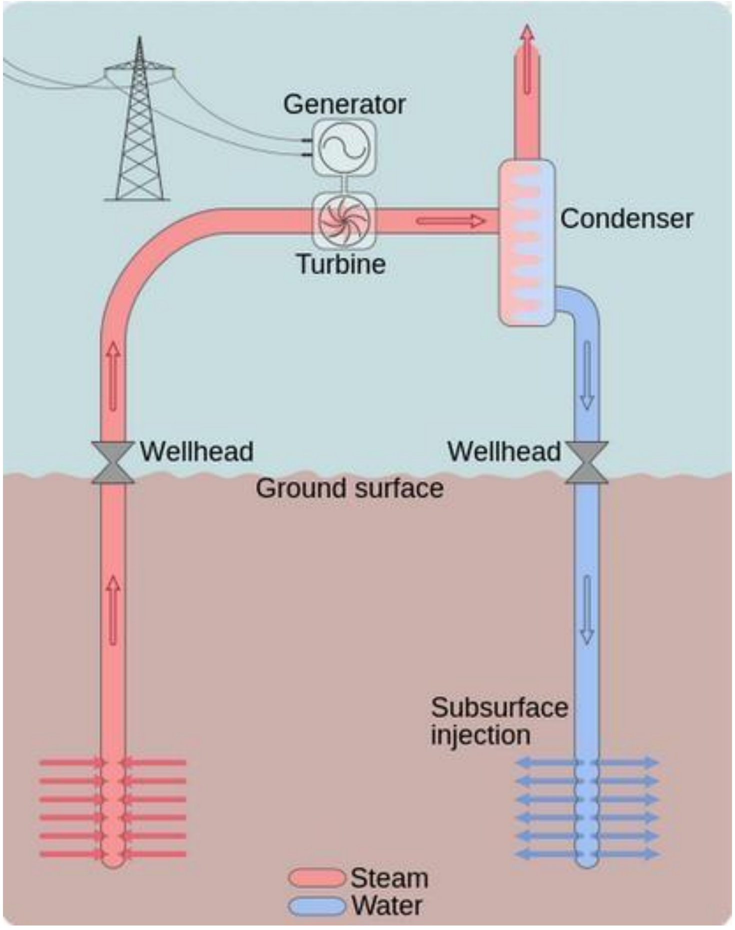
Geothermalpowerplants are used in order to generate electricity bythe useof geothermal energy (the Earth's internal thermal energy). They essentially work the same asa coal or nuclear power plant, the main difference being the heat source. With geothermal, theEarth'sheatreplacestheboilerofacoalplantorthereactor ofa nuclearplant.

Hotwater or steam isextracted from theEarth through aseriesof wellsandfeedsthe power plant. In most geothermal plants the water pulled up from the ground is returnedbacktothesubsurface.Therateofwaterusedisoftenlargerthantherateofwaterreturned,somake-upwatersuppliesaregenerallyneeded.

There are 3 main types of geothermal power plants, with theflash cycle being themost common. The choice of plant depends on how much geothermal energy is available, andhow hot the resource is. The hotter the resource, the less fluid needs to flow from the groundtotakeadvantageofit,themoreusefulitis.Somedetailsofeachplantmaybeseenbelow:

1. **DRYSTEAM PLANTS**

These plants use dry steam that is naturally produced in the ground. This steam travelsfromtheproductionwelltothesurfaceandthroughaturbine,andaftertransferring itsenergy to the turbine it condenses and is injected back into the Earth. These types are theoldesttypes of geothermal powerplants, thefirstone was builtbackin 1904in Italy.Because this type of power plant requires the highest temperatures they can only be usedwherethetemperatureundergroundisquitehigh,butthistyperequirestheleastfluidflow.

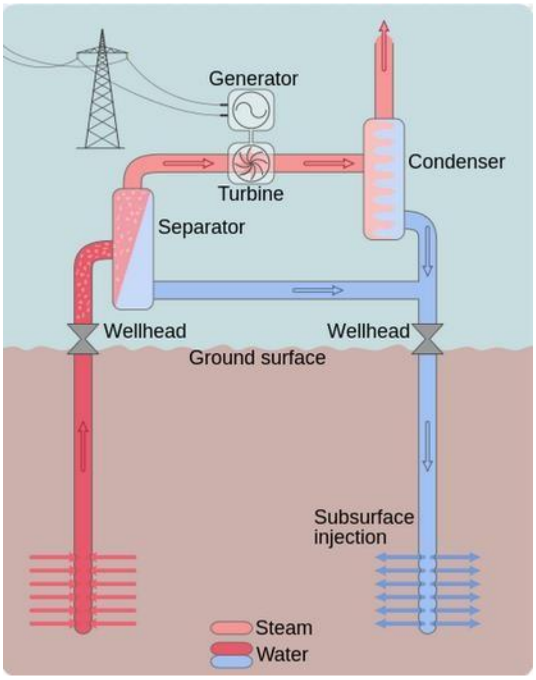


2. FLASHCYCLESTEAMPLANT

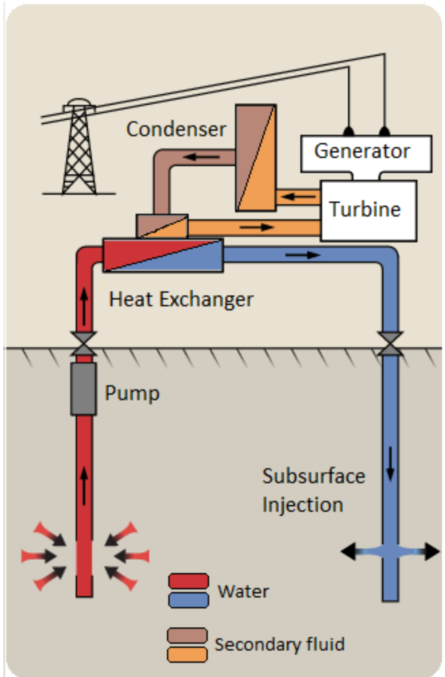
These types are the most common due to the lack of naturally occurring high-qualitysteam.In thismethod, water mustbe over 180°C, and underits own pressure itflowsupwards through the well. This is a lower temperature than dry steam plants have. As itspressure decreases, some of the water "flashes" to steam, which is passed through the turbinesection. The remaining water that did not become steam is cycled back down into the well,and can also be used for heating purposes. The cost of these systems is increased due to morecomplexparts,howevertheycanstillcompetewithconventionalpowersources.

3. BINARYCYCLEPLANT

Binary power plants are expected to be the most commonly used type of geothermalpower plant in the future, as locations outside of the known hot spots begin to use geothermalenergy.[3] This is because binary cycle plants can make use of lower temperature water thanthe other two types of plants. They use a secondary loop (hence the name "binary") whichcontains a fluid with a low boiling point, such as pentane or butane. The water from the wellflows through a heat exchanger which transfersits heat to thisfluid,which vaporizes due toits low boiling point. It is then passed through a turbine, accomplishing the same task assteam.



Flashcycle steamplant



Binarycycleplant

BIOMASS POWERSYSTEMS

Biomass is used for facility heating, electric power generation, and combined heat andpower. The term biomass encompasses a large variety of materials, including wood fromvarioussources,agriculturalresidues,andanimalandhumanwaste.

Biomass can be converted into electric power through several methods. The mostcommon is directcombustion of biomassmaterial,such as agricultural waste or woodymaterials. Other options include gasification, pyrolysis, and anaerobic digestion. Gasificationproduces a synthesis gas with usable energy content by heating the biomass with less oxygenthan needed for complete combustion. Pyrolysis yields bio-oil by rapidly heating the biomassintheabsenceof oxygen.Anaerobicdigestionproducesarenewablenatural gaswhenorganicmatterisdecomposedbybacteriainthe absence ofoxygen.

Differentmethodsworkbetwithdifferenttypesofbiomass.Typically,woodybiomass such as wood chips, pellets, and sawdust are combusted or gasified to generateelectricity. Corn stover and wheat straw residues are baled for combustion or converted into agasusingananaerobicdigester.Verywetwastes,likeanimalandhumanwastes,areconverted into a medium-energy content gas in an anaerobic digester. In addition, most othertypes of biomass can be converted into bio-oil through pyrolysis, which can then be used inboilersandfurnaces.

Mostbiopowerplantsusedirect-firedcombustionsystems.Theyburnbiomassdirectly to produce high-pressure steam that drives a turbine generator to make electricity. Insome biomass industries, the extracted or spent steam from the power plant is also used formanufacturingprocessesortoheatbuildings.Thesecombinedheatandpower(CHP)systems greatly increase overall energy efficiency to approximately 80%, from the standardbiomass electricity-only systems with efficiencies of approximately 20%. Seasonal heatingrequirementswillimpacttheCHPsystemefficiency.

Asimplebiomasselectricgenerationsystemismadeupofseveralkeycomponents. Forasteamcycle, this includessomecombinationofthefollowingitems:

- Fuelstorageandhandlingequipment
- Combustor/furnace
- Boiler
- Pumps
- Fans
- Steamturbine

- Generator
- Condenser
- Coolingtower
- Exhaust /emissionscontrols
- Systemcontrols(automated).

Direct combustion systems feed a biomass feedstock into a combustor or furnace,where the biomass is burned with excess air to heat water in a boiler to create steam. Insteadofdirectcombustion,somedevelopingtechnologiesgasifythebiomasstoproduceacombustible gas, and others produce pyrolysis oils that can be used to replace liquid fuels.Boiler fuel can include wood chips, pellets, sawdust, or bio-oil. Steam from the boiler is thenexpanded througha steamturbine,whichspinsto runageneratorandproduceelectricity.

In general, all biomass systems require fuel storage space and some type of fuel handlingequipmentand controls. A system using wood chips, sawdust, or pellets typically use abunkerorsiloforshort-termstorageandanoutsidefuelyardforlargerstorage.Anautomatedcontrolsystemconveysthefuelfromtheoutsidestorageareausingsomecombination of cranes, stackers, reclaimers, front-end loaders, belts, augers, and pneumatictransport. Manual equipment, like frontloaders, can be used to transfer biomass from thepiles to the bunkers, but this method will incur significant cost in labor and equipmentoperationsandmaintenance(O&M).Alesslabor-intensiveoptionistouseautomatedstackers to build the piles and reclaimers to move chips from the piles to the chip bunker orsilo.

Wood chip-fired electric power systems typically use one dry ton per megawatt-hourof electricity production. This approximation is typical of wet wood systems and is useful fora first approximation of fuel use and storage requirements but the actual value will vary withsystemefficiency.Forcomparison,thisisequivalentto20%HHVefficiencywith17MMBtu/tonwood.

Most wood chips produced from green lumber will have a moisture content of 40% to55%, wet basis, which means that a ton of green fuel will contain 800 to 1,100 pounds ofwater. This water will reduce the recoverable energy content of the material, and reduce theefficiencyoftheboiler,asthewatermustbeevaporatedinthefirststagesofcombustion.

Thebiggestproblemswithbiomass-firedplantsareinhandlingandpre-processingthefuel.Thisisthecasewithbothsmallgrate-firedplantsandlargesuspensionfiredplants.

Dryingthebiomassbeforecombustingorgasifyingitimprovestheoverallprocessefficiency,butma ynotbe economicallyviableinmanycases.

Exhaustsystemsareusedtoventcombustionby-productstotheenvironment.Emission controls might include a cyclone or multi-cyclone, a baghouse, or an electrostaticprecipitator. The primary function of all of the equipment listed is particulate matter control,andislistedin orderofincreasingcapitalcostandeffectiveness.Cyclonesandmulti-cyclones can be used as pre-collectors to remove larger particles upstream of a baghouse(fabricfilter)orelectrostatic precipitator.

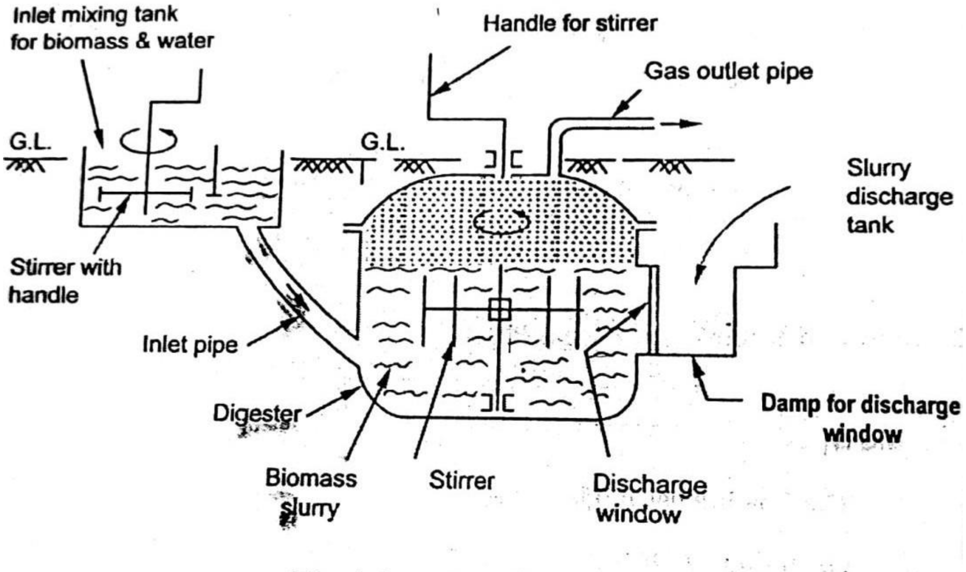
In addition, emission controls for unburned hydrocarbons, oxides of nitrogen, andsulfurmightberequired,dependingonfuelpropertiesandlocal,state,andFederalregulations.

1. FIXEDDOMETYPEDIGESTERBIOGASPLANT

A fixed-dome plant consists of a digester with a fixed, non-movable gas holder, whichsits on top of thedigester.When gas production starts, theslurry is displacedintothecompensation tank. Gas pressure increases with the volume of gas stored and the heightdifference between the slurry level in the digester and the slurry level in the compensationtank. The costs of afixed-dome biogas plantare relatively low. It is simple as nomovingparts exist. There are also no rusting steel parts and hence a long life of the plant (20 years ormore) can be expected. The plant is constructed underground, protecting it from physicaldamage and saving space. While the underground digester is protected from low temperaturesat night and during cold seasons, sunshine and warm seasons take longer to heat up thedigester. No day/night fluctuations of temperature in the digester positively influence thebacteriological processes.Theconstruction of fixeddomeplantsislabor-intensive, thuscreatinglocal employment. Fixed-dome plants are noteasy tobuild. They should only bebuilt where construction can be supervised by experienced biogas technicians. Otherwiseplantsmaynotbegas-tight(porosityandcracks).

A fixed-dome plant comprises of a closed, dome-shaped digester with an immovable,rigid gas-holder and a displacement pit, also named 'compensation tank'. The gas is stored inthe upper part of the digester. When gas production commences, the slurry is displaced

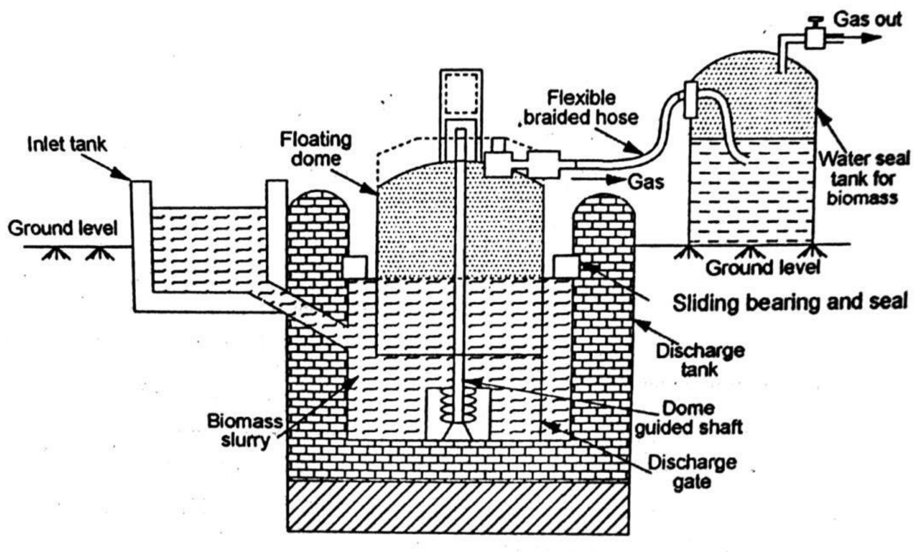
intothecompensatingtank.Gaspressureincreaseswiththevolumeofgasstored,i.e.withthe heightdifferencebetweenthetwoslurrylevels.If thereislittlegasinthegas-holder,thegaspressureislow.



Fixed dome type digester biogas plant

2. FLOATINGGASHOLDERTYPEDIGESTER

The floating gas holder type bio gas plant consists of a dome shaped gas holder madeof steel for collecting bio gas. The dome shaped gas holder is not fixed but is moveable andfloats over the slurry presentin the digester tank. Due to this reason, this biogas plantiscalledfloatinggasholdertypebiogas plant.



Floating gasholder type digester

Slurry is prepared by mixing water in cattle dung in equal proportion in mixing tank. Theslurry is then injected into a digester tank with the help of inlet pipe. The digester tank is aclosed underground tank made up of bricks. Inside the digester tank, the complex carboncompoundspresentinthecattledungbreaksintosimplersubstancesbytheactionofanaerobic microorganismsinthepresenceofwater.Thisanaerobicdecompositionofcomplex carbon compounds present in cattle dung produces bio gas and gets completed inabout 60 days. The bio gas so produced starts to collect in floating gas holder and is suppliedtohomesthroughpipes.Andthespentslurryisreplacedfromtimetotimewithfreshslurrytoc ontinuetheproductionofbiogas.

FUELCELLPOWERSYSTEMS

1. HYDROGEN-OXYGENFUELCELL

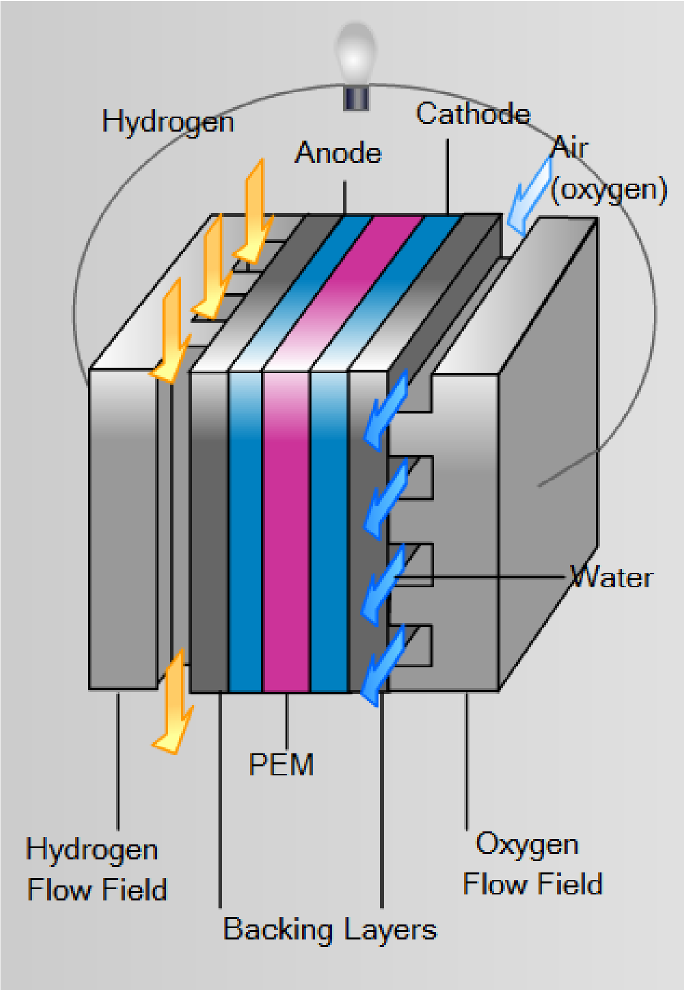
A fuel cell is a device that converts chemical potential energy (energy stored in molecularbonds) into electrical energy. A PEM (Proton Exchange Membrane) cell uses hydrogen gas(H_2)andoxygengas(O_2)asfuel.Theproductsof thereactioninthecellarewater,electricity,andheat. Thisisabigimprovement overinternal combustion engines,coalburning powerplants,andnuclearpowerplants,allofwhichproduce harmfulby-products

Theanode,thenegativepostofthefuelcell,hasseveraljobs.Itconductstheelectronsthat are freed from the hydrogen molecules so that they can be used in an external circuit. Ithas channels etched into it that disperse the hydrogen gas equally over the surface of thecatalyst.

The cathode, the positive post of the fuel cell,has channels etchedinto itthat distributethe oxygen to the surface of the catalyst. It also conducts the electrons back from the externalcircuit to the catalyst, where they can recombine with the hydrogen ions and oxygen to formwater.

The electrolyte is the proton exchange membrane. This specially treated material, whichlooks something like ordinary kitchen plastic wrap, only conducts positively charged ions.The membrane blocks electrons. For a PEMFC, the membrane must be hydrated in order tofunctionandremainstable.

Thecatalystisaspecialmaterialthatfacilitatesthereactionofoxygenandhydrogen.Itisusuallymadeofpla tinumnanoparticlesverythinlycoatedontocarbonpaperorcloth.The catalystisroughandporoussothatthemaximumsurfaceareaoftheplatinumcanbeexposedto thehydrogenoroxygen.Theplatinum-coated sideofthecatalystfacesthePEM.



As the name implies, the heart of the cell is the proton exchange membrane. It allowsprotons topass throughitvirtually unimpeded,whileelectrons areblocked.So,when theH_2 hits the catalyst and splits into protons and electrons (remember, a proton is the same as an$H+$ ion) the protons go directly through to the cathode side, while the electrons are forced totravel through an external circuit. Along the way they perform useful work, like lighting abulb or driving a motor, before combining with the protons and O_2 on the other side toproduce water.

How does it work? Pressurized hydrogen gas (H_2) entering the fuel cell on the anodeside. This gas is forced through the catalyst by the pressure. When an H_2 molecule comes incontactwith the platinum on the catalyst, itsplits into twoH+ ions and twoelectrons (e-).The electrons are conducted through the anode, where they make their way through theexternal circuit (doing useful work such as turning a motor) and return to the cathode side ofthe fuelcell.

Meanwhile, on the cathode side of the fuel cell, oxygen gas (O_2) is being forcedthrough the catalyst, where it forms two oxygen atoms. Each of these atoms has a strongnegative charge. This negative charge attracts the two H+ ions through the membrane, wherethey combinewithanoxygenatom andtwooftheelectronsfrom theexternalcircuittoforma watermolecule(H_2O).

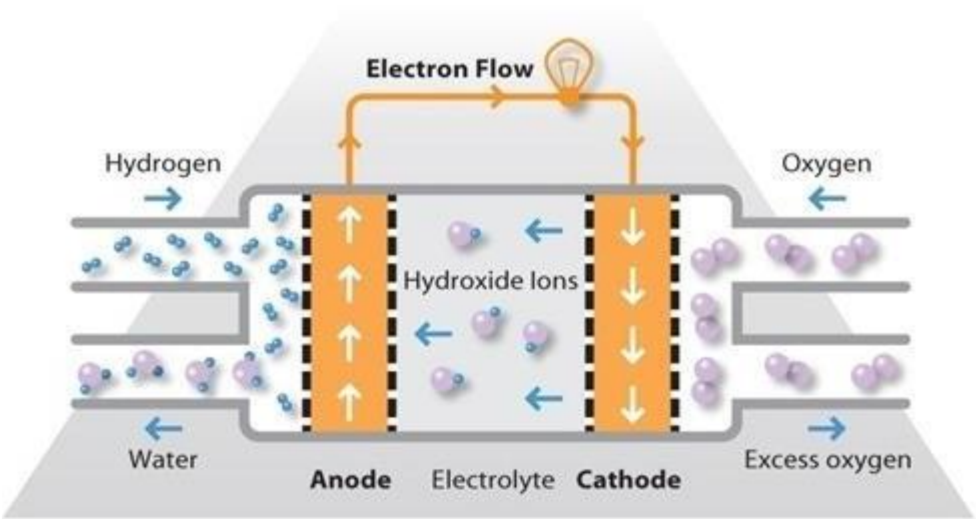
All these reaction occurs in a so called cell stack. The expertise then also involves thesetupofacompletesystemaroundcore componentthatisthe cellstack.

The stack will be embedded in a module including fuel, water and air management, coolantcontrol hardware and software. Thismodule will then beintegrated in a complete system tobe usedindifferentapplications.

Due to the high energetic content of hydrogen and high efficiency of fuel cells (55%),this great technology can be used in many applications like transport (cars, buses, forklifts,etc)andbackuppowertoproduceelectricityduringa failure ofthe electricitygrid.

2. ALKALINEFUELCELLS

Alkaline fuel cells (AFCs) were one of the first fuel cell technologies to be developed andwere originally used by NASA in the space programme to produce both electricity and wateraboardspacecraft.AFCscontinuedtobeusedonNASAspaceshuttlesthroughouttheprogram me,alongside alimitednumberofcommercialapplications.



AFCs use an alkaline electrolyte such as potassium hydroxide in water and are generallyfuelled with pure hydrogen. The first AFCs operated at between 100ºC and 250ºC but typicaloperatingtemperaturesarenowaround70ºC.Asaresultof thelowoperatingtemperature,it

is not necessary to employ a platinum catalyst in the system and instead, a variety of non-precious metals can be used as catalysts to speed up the reactions occurring at the anode andcathode. NickelisthemostcommonlyusedcatalystinAFC units.

Duetotherateatwhich thechemicalreactionstakeplacethesecellsofferrelativelyhighfueltoelectricityconversionefficiencies ,ashighas60%insome applications.