Hydrogen Gas-An Initiative for Coherent Use Of Renewable Energy

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Abstract: A fuel is any material that can be made to react with other substances so that it releases heat energy or energy to do work. The heat energy released by reaction of fuels is converted into mechanical energy through a heat engine. Hydrogen fuel is a zero-emission fuel when burned with oxygen and can be a perfect alternative of conventional fuels due to its high combustion energy. Hydrogen fuel can be used in electrochemical cells or internal combustion engines to power vehicles or electric devices. To a certain extent, there are some solutions to where and when the renewable energy sources should be used, stronger electricity supply, the use of distributed generation which in longer term, means the development of hydrogen economy. Hydrogen fuel can also be used as a transport fuel which in turn results on not being dependent on the world's declining reserves of oil. Hydrogen fuel has also been used in rocket propulsions for the generation of required heat. Even though hydrogen fuel has many benefits it needs to be carefully monitored as it has very low ignition energy and is highly flammable. If all these needs are met in the future, then there is no better alternative than hydrogen fuel to meet the needs of people. Production of hydrogen fuel is simple task but the most difficult task is the storage of hydrogen in the form of gas. It is clear that at room temperature a pressure of about 2000 psi is required to achieve densities in the order of gas phase. This storage is possible by carbon-fiber-reinforced high-pressure cylinders. The combustion of conventional fuel sources releases harmful gases which effect the environment, whose affects show considerable changes in future. By using hydrogen gas as a source of fuel, the amount of pollution liberated from the vehicles would be less when compared to that of conventional fuel sources because combustion of hydrogen yields large amount of water vapor and traces of nitrogen gas which is negligible.

Keywords: conventional fuels, gas phase, high combustion energy, hydrogen economy, low ignition energy, zero emission fuel.

I. INTRODUCTION

At the beginning of 21st century, fuel cells appeared to meet the power needs of different applications. A fuel cell is an electrochemical cell that converts the potential energy from the fuel into electricity through an electrochemical reaction of hydrogen fuel with oxygen or another oxidizing agent. Hydrogen is a clean fuel and efficient energy medium for fuel cells and other devices. Hydrogen can be produced from water, renewable energy sources and from other fuels. Hydrogen can be used as a supplement or substitute for the consumption of hydrocarbon fuels and fossil fuels in an environmental friendly manner. The large-scale production of hydrogen as a fuel would reduce the consumption of fossil fuels and keep the air clean from pollution. Hydrogen can be produced from Electrolytic, photo-biological, photo-electrolysis and thermo-chemical production technologies and are currently under development and use. The aim of the hydrogen program is to expand the role of hydrogen as a fuel for surface transportation. Production of hydrogen occurs at a temperature of 700-1100oC and the efficiency ranges between 65-70%. Hydrogen can also be produced from water electrolysis, by splitting the oxygen and the hydrogen molecules and this reaction provides an efficiency of 70-80%. Once the required efficiency is reached, it can be used similarly to natural gas and during combustion can produce a temperature of 2000oC. Hydrogen, being the lightest material in the universe can be easily transported with the aid of polyethylene pipes or carbon fiber reinforced high pressure cylinders from which the leak is expected to be as low as 0.01%. Also due to the production of hydrogen fuel tackling environmental problems would become possible and would become a great leap in human history.

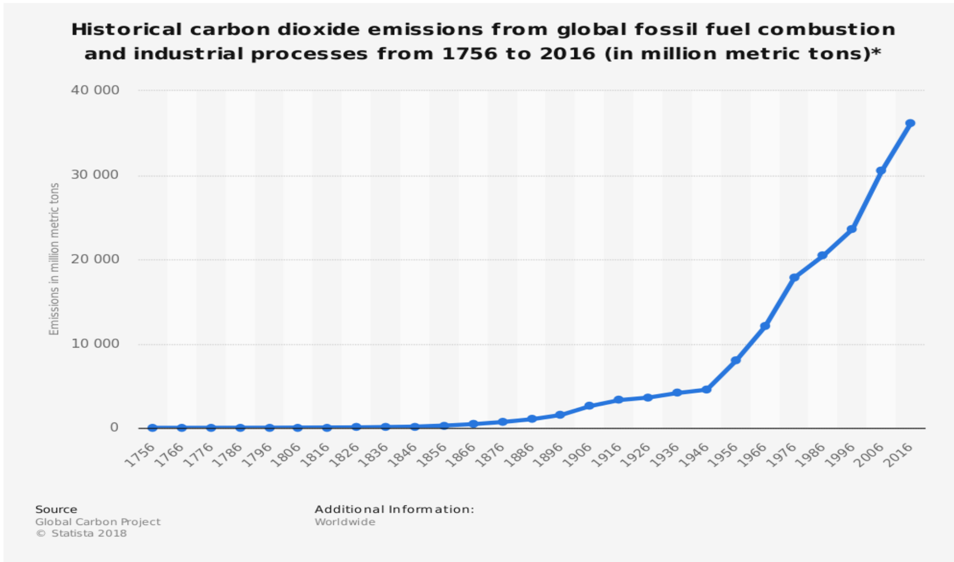

Fig 1. Depicts the carbon dioxide emission from fossil fuels since the Industrial Revolution

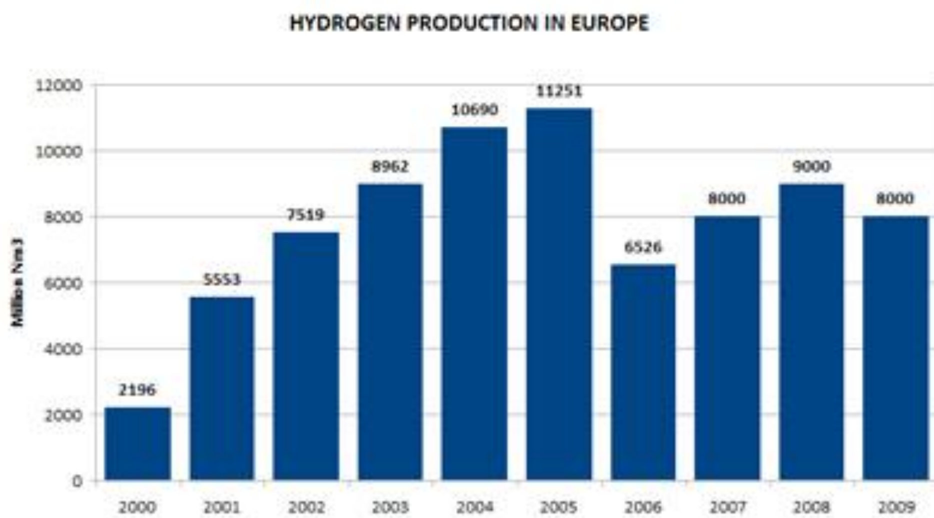

Fig 2. Depicts the production of hydrogen in Europe over the years

II. SOURCES OF HYDROGEN

Hydrogen does not exist alone in nature. Conventional energy sources such as wood, coal, natural gas and petroleum, have been used for a long time. These sources have been depleting at an alarming rate due to increase in population and living standards. Hydrogen is acclaimed to be a new energy carrier of the future. It is one of the potential solutions to the current energy and environmental pollution crises due to its carbon free and environmentally friendly criteria. Hydrogen is primarily produced by steam reforming of natural gas. Other major sources include naphtha or oil reforming of refinery or other industrial off-gases, and partial oxidation of coal and other hydrocarbons. There are four main sources for the commercial production of hydrogen: natural gas, oil, coal and electrolysis; which account for 48%, 30%, 18% and 4% of the world's hydrogen production respectively. Hydrogen can also be produced form the electrolysis of water, but it would require electricity. But on comparison electricity obtained from wind and solar cells are much cheaper than obtaining natural gas. This in turn gives us a new perspective that electrolysis of water for the production of hydrogen is much cheaper than steam reforming of natural gas. Also, another unconventional source of hydrogen is from dimethyl ether because it shows similar physical properties as that of liquified petroleum. Dimethyl ether can be obtained from the product of gasification of biomass or from methanol synthesis to dimethyl ether production. This dimethyl ether further undergoes decomposition in the presence of carbon monoxide and carbon dioxide. This reaction produces 6 moles of hydrogen for 1 mole of dimethyl ether. Hydrogen can also be obtained from the association of oxidation reaction of alloys in water. For such production isotopic hydrogen such as deuterium is required and this dissociation of water molecule undergoes with the treatment used on stainless steel and to increase the thickness of the film and this film can be a main source of hydrogen absorption in the alloy.

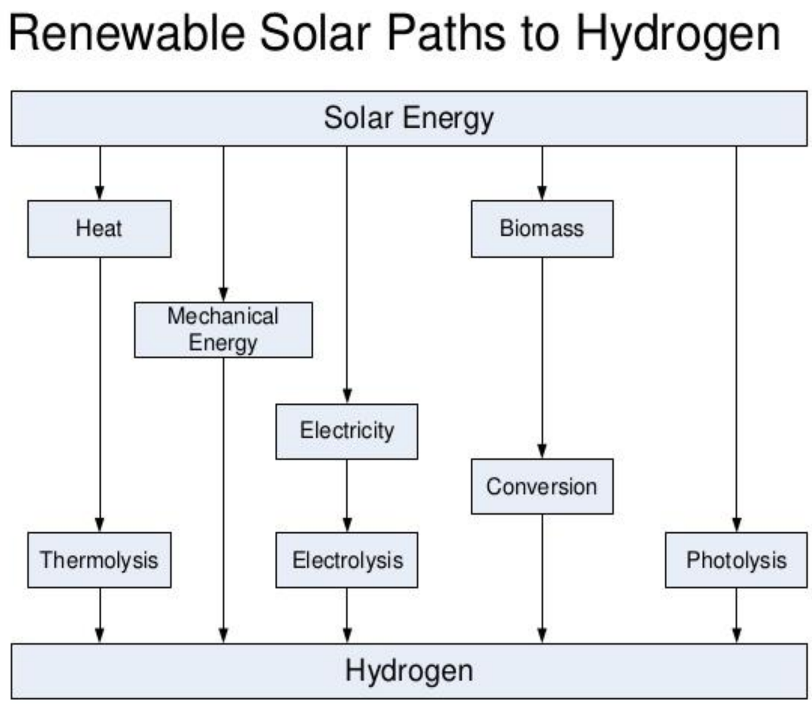

Fig 3. Flow diagram for the production of hydrogen from solar energy

2.1 Thermochemical

Thermochemical method involves the production of hydrogen from solar energy through thermochemical water splitting, which is also called as thermolysis where heat alone is used to decompose water to hydrogen and oxygen. This method gives an overall efficiency close to 50% where water will decompose at 2500oC. Thermochemical water splitting uses high temperatures-from concentrated solar cells or from the waste heat of nuclear power reactions. This is a long-term technology pathway, with potentially low or no greenhouse gas emission. For thermochemical method there are more than 300 thermochemical cycles, either purely thermal or hybrid. The disadvantage of this process is that the temperature must reach higher than 2000oC to achieve direct water decomposition without using any other chemicals. The temperature of direct thermolysis is too high for the selection of refractory materials and construction of equipment. Hence, the thermolysis is the product of mixture of hydrogen and oxygen, which indicate a considerable explosion risk at such high temperatures.

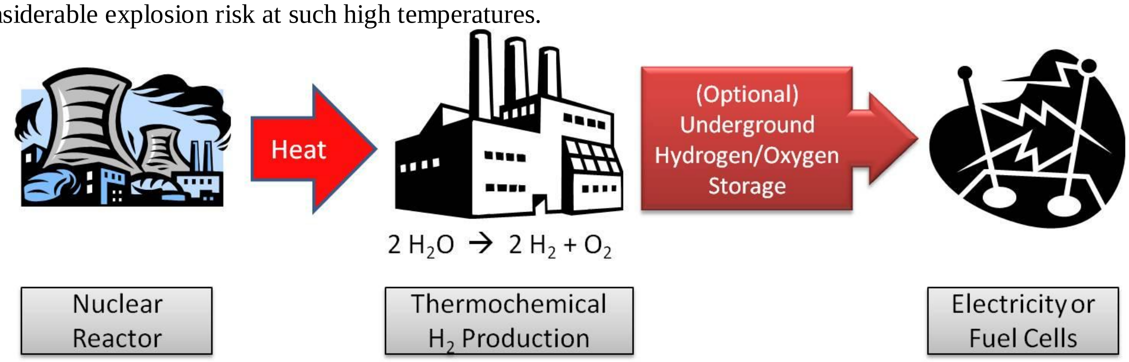

Fig 4. Depicts the flow of energy used for the production of hydrogen

2.2 Photo electrochemical

Photo electrolysis process usually used solar light to produce the hydrolysis of water. This process is also known as photo electrochemical. The basic set up for photo electrochemical consists of two electrodes immersed in an aqueous electrolyte contained within a vessel. One or both the electrodes are photoactive and are illuminated by solar light which can decompose water into hydrogen and oxygen. The principle of photo electrochemical process is when a photon with energy greater than the semiconductor material band gap is absorbed at the junction, an electron is released and a hole is formed. Thus an electric field is formed. The semiconductor material used in photo electrochemical process are similar to those used in photovoltaic solar electricity generation, but for photo electrochemical application the semiconductor is immersed in a water-based electrolyte, where sunlight energizes the water-splitting process. Photo electrochemical reactor can be constructed in panel form as electrode systems or as slurry-based particle systems, each approach with its own advantages and challenges. Photo electrochemical water splitting is a promising solar-to-hydrogen pathway for hydrogen production at semi-central and central scales, offering the potential for high conversion efficiency at low operation temperatures using cost-effective thin film or particle semiconductor materials.

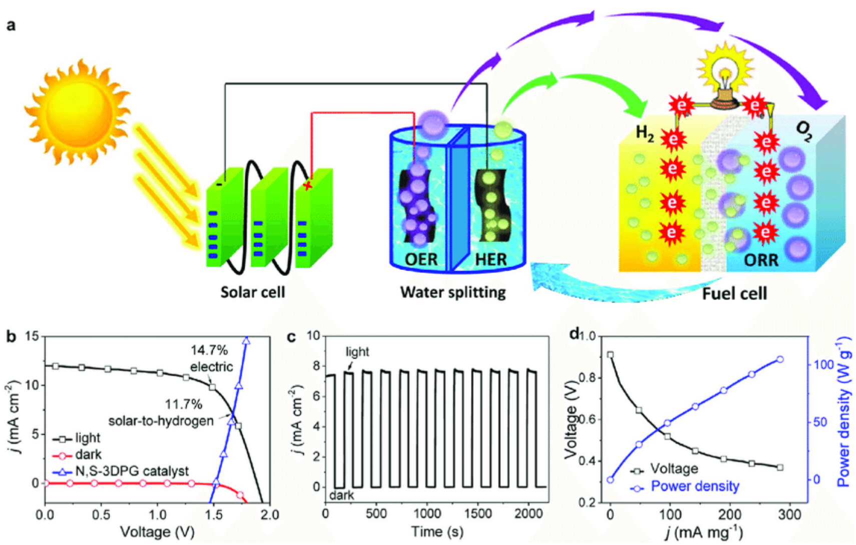

Fig 5. Represents the schematic flow during the production of hydrogen from Photo electrochemical cells

2.3 Electrochemical

Apart from gas reformation, water electrolysis is an electrochemical process permitting the decomposition of water to its constituent elements of hydrogen and oxygen using an electric current passing through two electrodes. The commercial low temperature electrolyzers have system efficiency of 56%-73%. The process of electrolysis can occur both at ambient temperatures and at high temperatures. Water electrolysis is useable when the electricity is purely from external power that is generated from photovoltaic panels or turbines driven by solar-generated steam or other gases. The electrodes are separated by an electrolytic conductor which permits transfer of ionic particles between the electrodes. In the process, electrical energy is supplied to the system and transformation of chemical energy takes place in the form of hydrogen. The electrolysis of water is not cost-effective unless the electricity comes from a renewable source like solar energy and wind energy. But when the electricity is obtained from renewable sources, the process become way cheaper and effective than methane refining process as natural gas is costly than producing electricity from renewables.

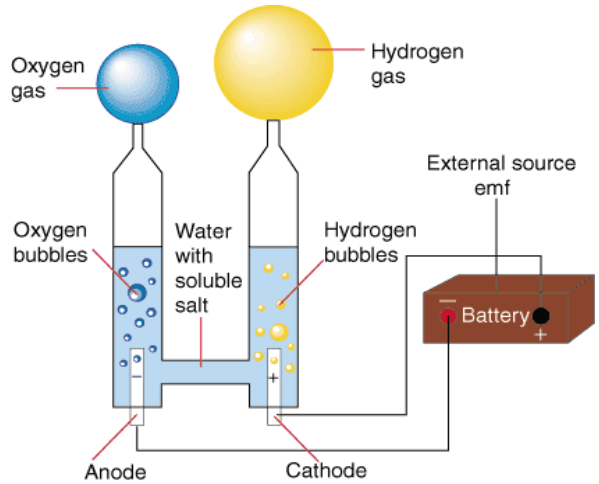

Fig 6. Represents the process that take place during electrolysis process of water for the production of hydrogen

2.4 Hydrogen production from biomass

Renewable biomass is as attractive alternative to fossil feedstock because of the potential for the essentially zero net CO2 impact. Unfortunately, hydrogen content in biomass is only 6-6.5% compared to almost 25% in natural gas. But there are a number of ways for producing hydrogen from biomass. They are:

Thermochemical gasification

Fast pyrolysis

Solar gasification

Super critical conversion and

Biological hydrogen production.

Gasification is a process that converts organic or fossil based carbonaceous materials at high temperatures, without combustion, with a controlled amount of oxygen or steam into carbon monoxide, hydrogen and carbon dioxide. The carbon monoxide reacts with water to form carbon dioxide and more hydrogen gas through a water gas shift reaction. Absorbers or special membranes can separate and purify hydrogen from this gas stream.

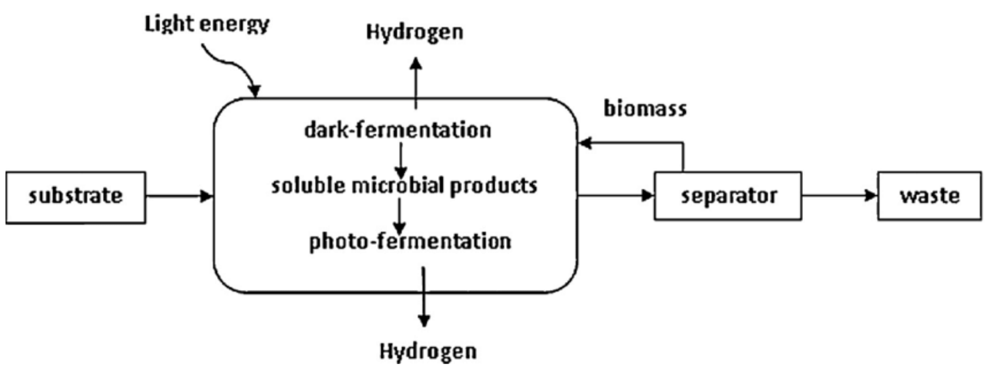

Fig 7. Depicts the schematic flow for production of hydrogen from biomass

III. RECENT WORKS IN THE PRODUCTION OF HYDROGEN

Recent work has started in the Orkneys, Scottish Islands closer to the Arctic Circle than to London are a renewable energy powerhouse, to produce hydrogen as a fuel using wind, wave and tidal energy. The islands are heavily exposed to the Atlantic and North Seas and are surrounded by powerful tides and strong winds. Due to the abundant availability of wind and tidal energy sources, this production has been possible. The H2 and O2 molecules available are broken from the H2O molecules present in water using electricity and these H2 molecules are compressed and stored for their usage in electricity and as a natural fuel which does not produce any pollutants on combustion. The production process is also a natural one and does not require external energy or heat sources for tapping the energy. They generate 140% of the electricity they need. In 2017, Orkney was the first to generate hydrogen from tidal power. It powers two schools on the islands, as well as ferries while they are docked and engineers are building world's first hydrogen-powered ferry to be ready by 2021. The Orkneys have more machines converting ocean energy into electricity than anywhere else in the world. But for the rest of the world, obtaining tidal and wind energy required for meeting the needs of people may be a difficult task. So in these places, production of hydrogen from steam reforming or electrolysis of water or production of hydrogen from biomass may be an easy task. Due to such production the overall cost for fuel may be drastically reduced and processes depending on fuel may become cheaper in turn benefitting the environment as well as that country's economy.

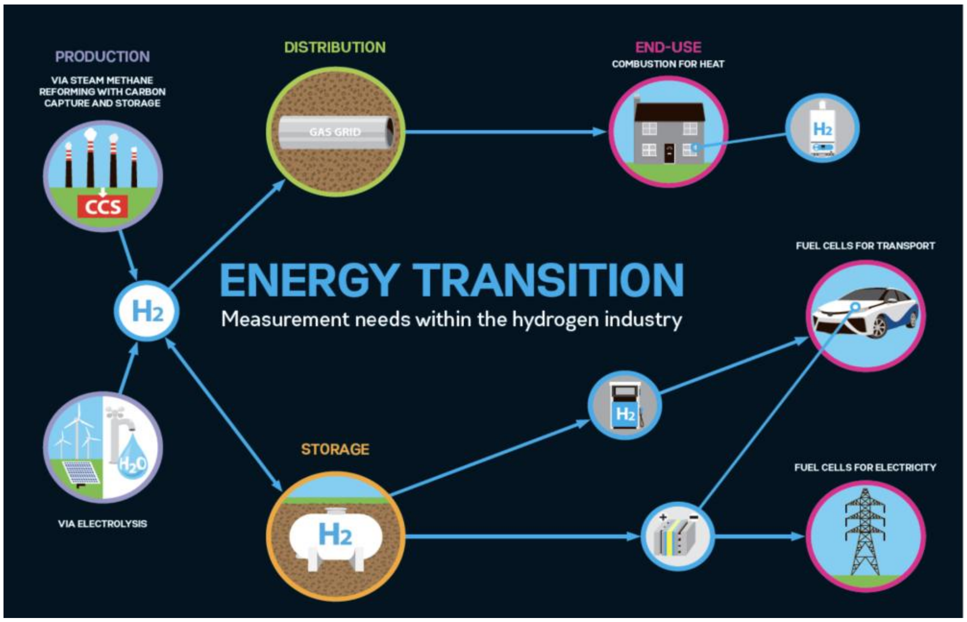

Fig 8. Represents the energy transition of hydrogen from one energy sector to another till the end consumer

IV. STORAGE OF HYDROGEN

Using hydrogen as a fuel is well understood. Coal gas produced from coal before the arrival of natural gas consists mainly of hydrogen and carbon monoxide. When burned, 1 kilogram of hydrogen will produce 120MJ of heat, assuming that the byproduct of water is released as vapor. Although this is nearly three times the energy per unit mass of petrol or diesel fuel it is highly flammable with very low ignition temperature due to which its combustion needs to be monitored regularly. Hydrogen also has the disadvantage of being a gas, with a low energy per unit volume at atmospheric pressure. It can also be stored in many ways:

As a gas in pressurized cylinders, typically at around 300 atmospheres which are made up of carbon fiber reinforced high-pressure cylinders.

As a liquid, although this requires its temperature to -253oC and the use of highly insulated storage.

Hydrogen can also be stored in batteries where in the given hydrogen diffuses to protons and electrons present in the anodic portion. These protons react with oxidants causing the formation of proton membranes where as the electrons are forced to travel through an external circuit supplying power. The protons and electrons are sent into the cathodic portion where oxygen is present and these protons and electrons react with oxygen to form water.

V. CONCLUSION

Hydrogen, one of the most economical gases available has wide applications and its traces are found in the earth's atmosphere. It has wide applications as a source of tidal energy. The sources of hydrogen are discussed in this paper which are from natural to electrolysis process. The solar path of sources of hydrogen gas is widely used for production of pure form of hydrogen. There are many ways to produce hydrogen gas from the sources available. In the process of production of hydrogen gas, photo-chemical process in the most efficient one and it is widely used across the globe. There are many recent works going on across the world to use hydrogen as a source of electricity and as a fuel. Many countries are using hydrogen as a source of electricity due to its availability in abundance in water. Hydrogen being environmental friendly can be used to substitute the conventional high toxic gas releasing agents used as a source of fuel. Hydrogen can be used as a fuel by compressing the gas and storing it in carbon-reinforced high pressure cylinders which are capable of sustaining a tensile strength of 4900 Mpa which will be helpful in storing a high pressure gas like hydrogen. These tanks are expected to range from 15-20% lighter than their nearest type IV cousins (plastic lined composite vessels). Hydrogen production also benefits the environment because after combustion only water vapor is liberated and this process has never been cheaper due to the advancement of technology.

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