Hydrogen Production from Renewable Energy Sources in India

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Abstract— Hydrogen from different renewable energy sources in india have potential to meet the energy demand of societies, Industries & transportation sector. Also by the use of hydrogen as a fuel reduce the greenhouse gases Emission, which are associated with our present, fossil fuel dominated energy system. For India the possibility to applied renewable energy for the production of Hydrogen it's very important aspect for the development economic future of the country. The use of hydrogen as a fuel in the future is seen as an alternative for countries without fossil fuel reserves. This paper shows the possibility of hydrogen technologies that use renewable energy sources and their different applications by use of solar & wind energy.

Key words: Renewable Energy, Hydrogen Energy ,Biogas Energy ,Solar Energy ,Wind Energy

I. INTRODUCTION

Energy is the engine that has driven the development of the India. The twenty first century has been a spectacular growth of the economies and living standards globally. All the previous energy such as water, wood and wind is replacing by the fossil fuels in transportation and power generation. These consume large amount of fossil fuels daily in all over world.

Crude oil, coal and gas are the main resources for world energy supply. The size of fossil fuel reserves will be diminished shortly due to continuous consumption. It also emits greenhouse gases. The changing climate is expected to have extremely grave consequences, leading to an increased number of "extreme" weather events, potential rises in sea level, and possible extinction of plant and animal species due to habitat loss.

There is lack of renewable technology for producing the energy and existing technology are not free from pollution which increase the greenhouse gas emission by burning of fossil fuels. In last few decades the development of the renewable energy to meet the demand of energy consumption is increased which emit less pollution than the fossil fuels. Also for achieving the energy security in india due to less availability of nonrenewable sources visualizing the use of renewable energy as a key or alternatives to solve the challenges.

A. Hydrogen as a Fuel:

Hydrogen is found in water, organic compounds, biomass, and hydrocarbons such as petrol, natural gas, methanol, and propane. Hydrogen is high in energy content as it contains 120.7 kilojoules/gram. This is the highest energy content per unit mass among known fuels. Thus, challenges are greater in the storage of hydrogen for civilian applications, as compared to storage of liquid fossil fuels. When burnt, hydrogen produces water as a byproduct and is therefore not only an efficient energy carrier but a clean, environmentally benign fuel as well. Hydrogen can be used for power generation and also for transport applications. It is possible to use hydrogen in internal combustion (IC) engines, directly or mixed with diesel and compressed natural gas (CNG) or hydrogen can also be used directly as a fuel in fuel cells to produce electricity. Hydrogen energy is often mentioned as a potential solution for several challenges that the global energy system is facing. The advantages are the fact that hydrogen use results in nearly zero emissions at endues, and that hydrogen opens up the possibility of decentralized production on the basis of a variety of fuels. But it is found that hydrogen will not play a major role in India without considerable research, technology innovations and cost reductions, mainly in fuel cell technology. Hydrogen is the smallest element, with one proton and one electron. It is highly abundant and has unique and important chemical properties Hydrogen gas (H2) is highly flammable and will burn in air at a very wide range of concentrations between 4 percent and 75 percent by volume. The enthalpy of combustion for hydrogen is 484 kJ/mol, and is described by the equation:

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g),\ \Delta H = -484\ \text{kJ mol}^{-1}$$

Hydrogen fuel is a zero-emission fuel which uses electrochemical cells, or combustion in internal engines, to power vehicles and electric devices. It is also used in the propulsion of spacecraft and might potentially be mass-produced and commercialized for passenger vehicles and aircraft.

Hydrogen is a great source of energy for a number of reasons, the biggest one being that it is so readily available. While it may take some work to access, there is no element in the universe as abundant as hydrogen. Another advantage to using hydrogen energy is that when burned, its leaves almost no harmful byproducts. In fact, when used in NASA's spaceships, the burned hydrogen gas leaves behind clean drinking water for the astronauts. World over about 96 % hydrogen is being produced using hydrocarbons i.e. natural gas (48%), oil(30%) and coal (18%) through steam reformation/partial oxidation/gasification processes. About 4% hydrogen is produced through electrolysis of water. The currently production of hydrogen energy is as shown in fig.1 from different sources in that only 4% is producing by the electrolysis process.

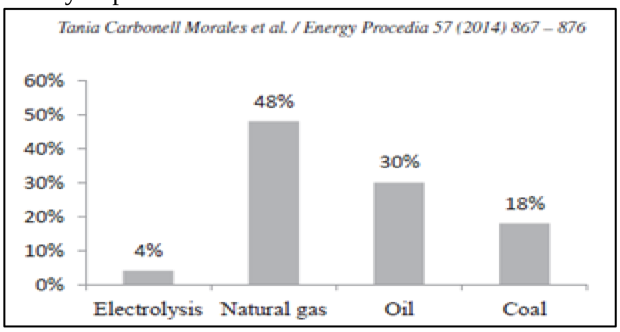

Fig. 1: Origin of Hydrogen Currently Produced Worldwide

Hydrogen can be produced from a number of sources, such as water, hydrocarbon fuels, biomass and chemical elements with hydrogen. The forms of energy that can drive a hydrogen production process can be classified in four categories: thermal, electrical, photonic, and biochemical energy. These kinds of energy can be obtained from primary energy (fossil, nuclear, and renewable) or from recovered energy through various paths. The following figure shows different ways to obtain hydrogen.

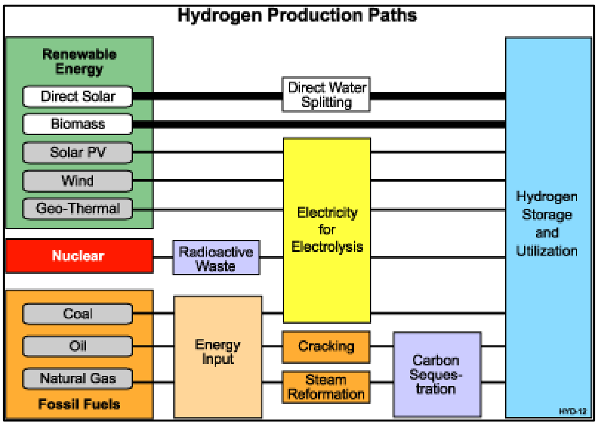

Fig. 2: Hydrogen Production Methods

Solar and wind energy can be harnessed to provide clean electricity to hydrogen-generating electrolyzes. In this way, hydrogen production can be a pathway for using renewable domestic energy sources to contribute directly to reducing greenhouse gases and reliance on imported transportation fuels. Linking nuclear power to H2 production would only ensure that industry chooses H2 technology compatible with industry's obsolete nuclear reactors.

Looking forward to a future based on sustainable development, hydrogen energy carrier, produced from renewable energy sources, is becoming more important. And in this field, the hydrogen produced with solar, wind and biomass use are presented as a suitable way to store, in the form of chemical energy, energy from the sun directly or indirectly.

B. Renewable Sources in India:

The electricity sector in India had an installed capacity of 267.637 GW as of end March 2015 and generated around 1048.5 BU for the period April 2014 - March 2015. Renewable Power plants constituted 27.25% of total installed capacity and Non-Renewable Power Plants constituted the remaining 72.75%. Power plant consume fossil fuels like coal, oil, natural gas which is export from the other country which reduce the economy of India by the development in the renewable sector we can reduce the use of fossil fuels. It also contributing to protecting the environment and reducing greenhouse gas emissions.

With about 300 clear, sunny days in a year, India's theoretical solar power reception, on only its land area, is about 5,000 trillion kilowatt-hours (kWh) per year. The daily average solar energy incident over India varies from 4 to 7 kWh/m2 with about 1,500–2,000 sunshine hours per year (depending upon location), which is far more than current total energy consumption.

Renewable energy including large hydro constitutes for only 28.8% of overall installed capacity in India. The total renewable energy potential from various sources in India is 2,49,188 MW. India till 31st March 2014 has been able to achieve only 12.95% of its renewable energy potential. The untapped market potential for overall renewable energy in India is 216918.39 MW which shows huge growth potential for renewable energy in India.

India has reasonably good potential for geothermal; the potential geothermal provinces can produce over 10,000 Mw of power. In India nearly 400 thermal springs occur.

The biomass atlas estimates surplus biomass availability at about 150 million metric tonnes per annum with a potential of over 18000 MW power generation capacity. Besides this, over 60 million tonnes per annum of municipal solid wastes with a potential of over 2300 MW and bagasse from sugar mills with a potential of over 5000 MW respectively are also available. Thus, the potential for installation of bioenergy projects including energy from biomass, municipal solid wastes and sugarcane bagasse is are estimated to be over 25000 MW.

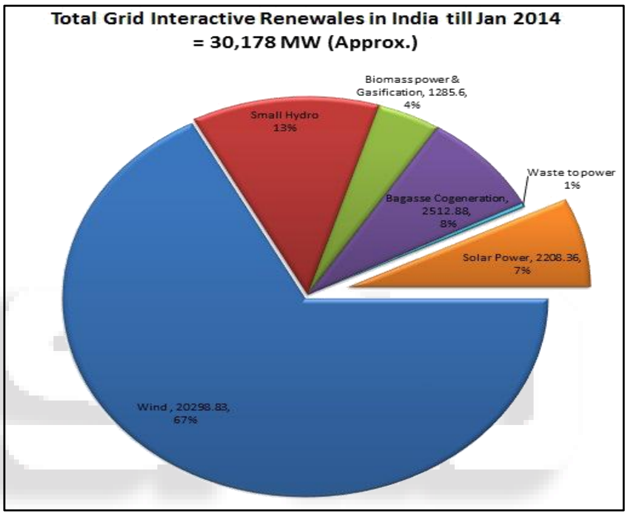

Fig. 3: Renewable Energy in India Till 2014

India has only around 25 equipment manufacturers listed as per the MNRE website, who fabricate almost the entire range of small hydro power equipment. As of now, India has an estimated potential of about 20,000 MW, about 80% of which is untapped. Further, up gradation of water mills and micro hydel projects is also being undertaken throughout the sector. Both these factors depict promising potential for an increase in domestic manufacturing.

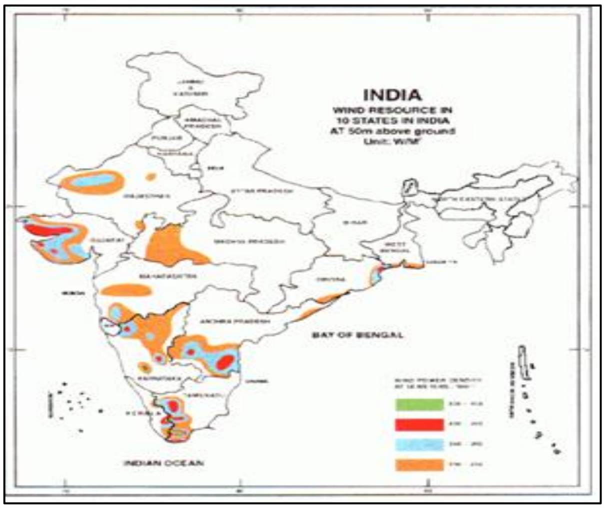

Fig. 4: Wind Resource in India 10 States

India has quite a few wind farms ; 6% of the total installed power for electricity generation are wind farms. However, only 1,9% of the electricity generated comes from wind energy.

From the above it can be seen that the renewable energy sources in India have a high potential, mainly solar, wind, biomass and geothermal energy. In MAKE IN INDIA project the Jawaharlal Nehru National Solar Mission aims to generate 20,000 MW of solar power by 2022. India's wind energy production can grow at least four to five times its current level to achieve the country's 60 GW wind energy potential.

II. HYDROGEN FROM RENEWABLE ENERGY SOURCES IN INDIA

In India fossil fuel are available in low quantity and also the production of hydrogen from fossil fuels are not economical , for this reason we will focus on the method of producing hydrogen by electrolysis of water, obtaining the necessary electricity using technologies that exploit renewable energy sources, including solar, wind, geothermal and biomass , which are the most promising sources at short-term development in the country.

Globally, over 95% of hydrogen is produced from hydrocarbons; about 4% is produced through electrolysis of water Hydrogen is also produced as a byproduct in chloralkali industries. There are several other methods to produce hydrogen that are at different stages of research and demonstration.

These methods include hydrogen production through

1) Biomass and biological route,
2) Photo electrochemical route,
3) Thermo chemical decomposition of water using nuclear energy or solar energy, and
4) Electrolysis using renewable energy (solar, wind).

A. *Hydrogen Production by Electrolysis:*

The electrolysis of water was discovered at the dawn of the first industrial revolution, in 1789 by German scientists Diemann and P Van Troostwijk. It consists in the decomposition of water into its constituent elements (hydrogen and oxygen) to the passage of an electric current between two electrodes within a body of water. The overall electrochemical reaction is as follows:

$$2\,H_2O(l) \rightarrow 2\,H_2(g) + O_2(g)$$

An electrical power source is connected to two electrodes, or two plates (typically made from some inert metal such as platinum, stainless steel or iridium) which are placed in the water. Hydrogen will appear at the cathode (the negatively charged electrode, where electrons enter the water), and oxygen will appear at the anode (the positively charged electrode). Assuming ideal faradaic efficiency, the amount of hydrogen generated is twice the amount of oxygen, and both are proportional to the total electrical charge conducted by the solution. However, in many cells competing side reactions dominate, resulting in different products and less than ideal faradaic efficiency. Electrolysis of pure water requires excess energy in the form of over potential to overcome various activation barriers. Without the excess energy the electrolysis of pure water occurs very slowly or not at all. This is in part due to the limited selfionization of water. Pure water has an electrical conductivity about one millionth that of seawater. Many electrolytic cells may also lack the requisite electro catalysts. The efficiency of electrolysis is increased through the addition of an electrolyte (such as a salt, an acid or a base) and the use of electrocatalysts.

The electrolysis of water in standard conditions requires a theoretical minimum of 237 kJ of electrical energy input to dissociate each mole of water.

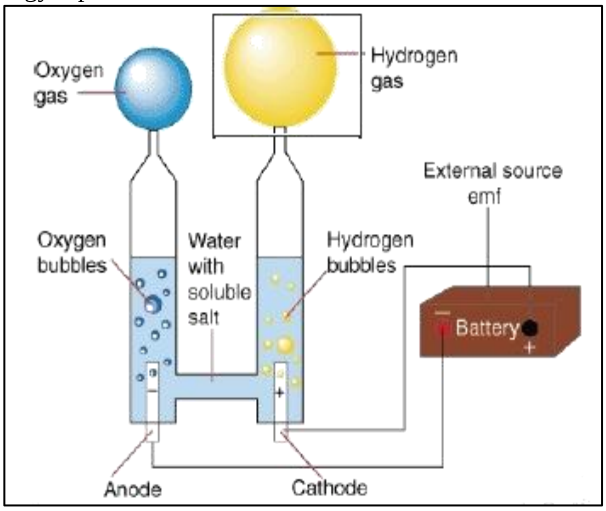

Fig. 5: Electrolysis of Water

As everyone knows a water molecule is formed by two elements: two positive Hydrogen ions and one negative Oxygen ion. The water molecule is held together by the electromagnetic attraction between these ions. When electricity is introduced to water through two electrodes, a cathode (negative) and an anode (positive), these ions are attracted to the opposite charged electrode. Therefore the positively charged hydrogen ions will collect on the cathode and the negatively charged oxygen will collect on the anode. When these ions come into contact with their respective electrodes they either gain or lose electrons depending on their ionic charge. (In this case the hydrogen gains electrons and the oxygen loses them) In doing so these, ions balance their charges, and become real, electrically balanced, bona fide atoms (or in the case of the hydrogen, a molecule).The reason this system isn't very efficient is because some of the electrical energy is converted into heat during the process.

B. *Hydrogen Production by Solar Energy:*

The use of solar energy to produce hydrogen can be conducted by two processes: water electrolysis using solar generated electricity and direct solar water splitting. When considering solar generated electricity, almost everyone talks about PV electrolysis. for the fueling station of 1,000 kg of hydrogen per day. Using the lower heating value of hydrogen, the electrical energy needed to generate one kg of hydrogen is 51 kWh (using an electrolyzer efficiency of 65%). This means that 1,000 kg/day of hydrogen will require 51,000 kWh per day of electricity. The amount of PV needed to supply 51,000 kWh can be estimated by dividing the kWh by 5 hours/day. Thus, 10,200 kWp or 10.2 megawatts of PV power will be needed for operating a 1000 kg/day hydrogen fueling station. Note that 1 kWp requires approximately 10 square meters in area for PV at 10% efficiency.

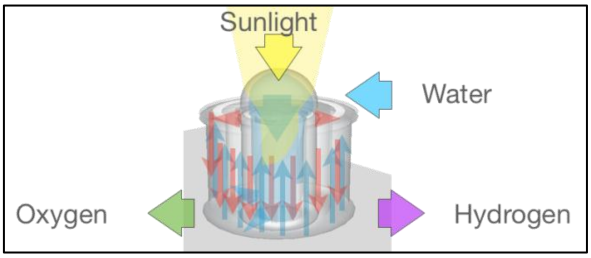

Fig. 6: Hydrogen By Solar Radiation

The second category, direct solar water splitting, refers to any process in which the solar energy is directly used to produce hydrogen from water without going through the intermediate electrolysis step. Examples include: photoelectrochemical water splitting this technique uses semiconducting electrodes in a photoelectrochemical cell to convert light energy into chemical energy of hydrogen. The high temperature thermochemical cycles can achieve excellent efficiencies (greater than 40 percent), but they must use concentrated solar receiver/reactors capable of reaching temperatures in excess of 800º C. There There are essentially two types of photoelectrochemical systems – one using semiconductors or dyes and another using dissolved metal complexes. Photobiological – these involve the generation of hydrogen from biological systems using sunlight. Certain algae and bacteria can produce hydrogen under suitable conditions. Pigments in algae absorb solar energy, and enzymes in the cell act as catalysts to split water into its hydrogen and oxygen constituents. High temperature thermochemical cycles – these cycles utilize solar heat to produce hydrogen by water splitting using thermochemical steps.

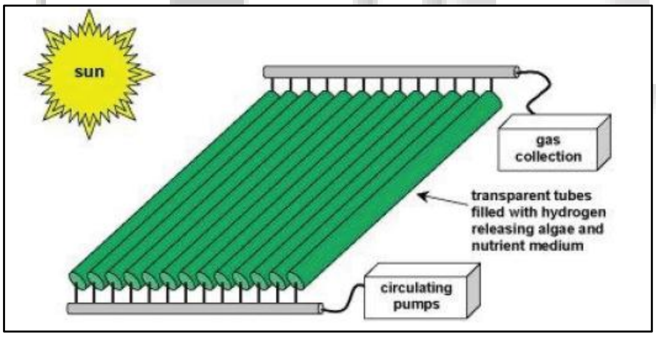

Fig. 7: Hydrogen Production from Algae by Using Solar Energy

Hydrogen production with the help of algae, its efficiency must be increased by a factor of 10 to 100 compared to the natural process the production of hydrogen from renewable energy carriers involved the electrolytic splitting of water. Expensive and rare precious metals like platinum are currently required for this purpose. Biological hydrogen production by photosynthetic microorganisms for example, requires the use of a simple solar reactor such as a transparent closed box, with low energy requirements. If such processes could be made to work on a large scale, we have a renewable source of hydrogen. If the entire capacity of the photosynthesis of the algae could be directed toward hydrogen production, 80 kilograms of hydrogen could be produced commercially per acre per day.

C. Hydrogen Production by Biomass Energy:

Gasification is a two-step process in which a solid fuel (biomass or coal) is thermochemically converted to a low- or medium-energy-content gas. Natural gas contains 35 MJ/Nm3. Air-blown biomass gasification results in approximately 5 mJ//m3; oxygen-blown in 15 mJ/m3. In the first reaction, pyrolysis, the dissociated and volatile components of the fuel are vaporized at temperatures as low as 600°C (1100°F). Included in the volatile vapors are hydrocarbon gases, Hydrogen, carbon monoxide, carbon dioxide, tar, and water vapor. Because biomass fuels tend to have more volatile components (70-86% on a dry basis) than coal (30%), pyrolysis plays a larger role in biomass gasification than in coal gasification. Gas phase thermal cracking of the volatiles occurs, reducing the levels of tar. Char (fixed carbon) and ash are the pyrolysis byproducts that are not vaporized. In the second step, the char is gasified through reactions with oxygen, steam, and hydrogen. Some of the unburned char may be combusted to release the heat needed for the endothermic pyrolysis reactions. Gasification coupled with water-gas shift is the most widely practiced process route for biomass to hydrogen. Thermal, steam and partial oxidation gasification technologies are under development around the world. Feedstocks include both dedicated crops and agricultural and forest product residues of hardwood, softwood and herbaceous species.

Thermal gasification is essentially high severity pyrolysis although steam is generally present.

$$\text{Biomass} + \text{Energy} \Rightarrow CO + H_2 + CH_4 + ..$$

By including oxygen in the reaction gas the separate supply of energy is not required, but the product gas is diluted with carbon dioxide and, if air is used to provide the oxygen, then nitrogen is also present.

$$\text{Biomass} + O_2 \Rightarrow CO + H_2 + CO_2 + \text{Energy}$$

All of these gasifier examples will need to include significant gas conditioning, including the removal of tars and inorganic impurities and the conversion of CO to H2 by the water-gas shift reaction:

$$CO + H_2O \rightarrow CO_2 + H_2$$

The reaction of pyrolisis is endothermic:

$$\text{Biomass} + \text{Energy} \Rightarrow \text{Bio-oil} + \text{Char} + \text{Gas}$$

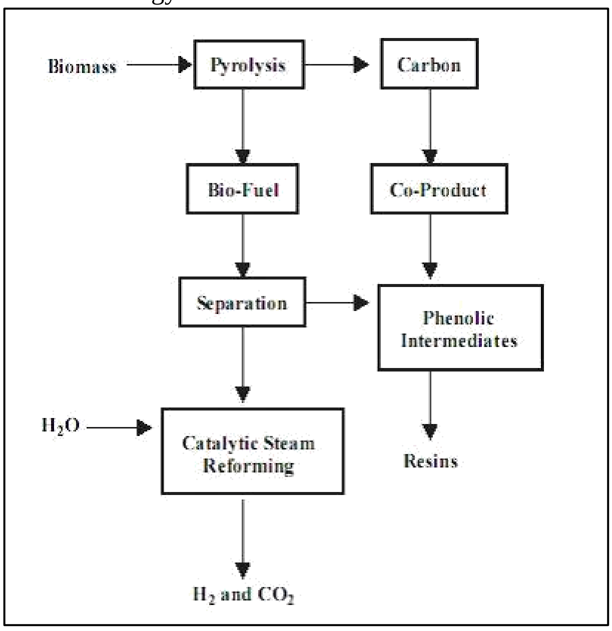

Fig. 8: Pyrolysis Process For Hydrogen Production

Pyrolysis to hydrogen and carbon is being explored as a viable technology for carbon sequestration although most work is applied to natural gas pyrolysis. Pyrolysis produces a liquid product called bio-oil, which is the basis of several processes for the development of fuels, chemicals and materials. Then from remaining gases the hydrogen gas is separate.

D. Hydrogen from Wind Energy:

Two wind turbine technologies are available: a Northern Power Systems 100kW wind turbine and a Bergey 10kW wind turbine. Both wind turbines are variable speed, meaning the blade's speed varies with wind speed. Such wind turbines produce alternating current (AC) that varies in magnitude and frequency (known as wild AC) as the wind speed changes.

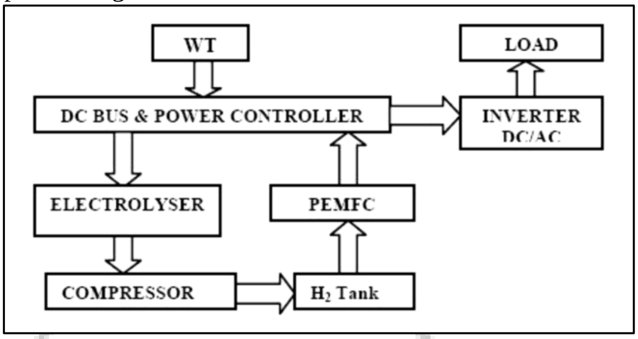

Fig. 9: Hybrid Wind- Hydrogen System Diagram

The energy from the 10kW wind turbine is converted from its wild AC form to direct current (DC) and then used by the electrolyzer stack to produce hydrogen from water. The energy from the 100kW wind turbine is monitored with a power transducer, and stack current on the 33kW alkaline stack is varied proportionally.

III. CONCLUSION

Through this paper aims to show the possibility that the hydrogen produced from solar, wind and biomass in the current Indian context, in addition to becoming an alternative fuel for power generation and other industrial applications or in the transport sector, are key elements of Indian society development. Integrated systems of renewable energy sources, wind, solar and hydrogen are displayed as an alternative for electricity production to India and as energy storage elements, allowing avoid the intermittent energy production using renewable energy sources.

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