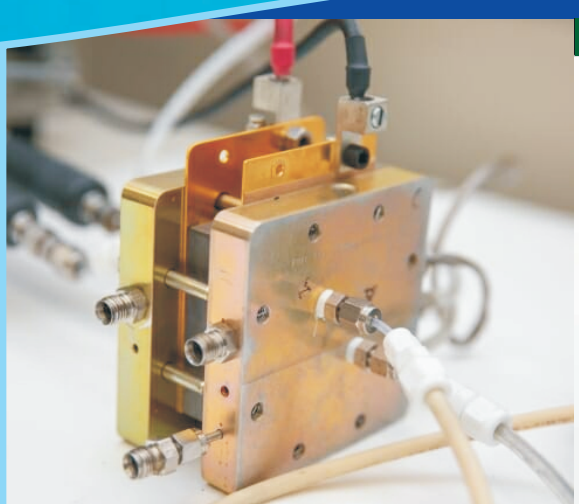
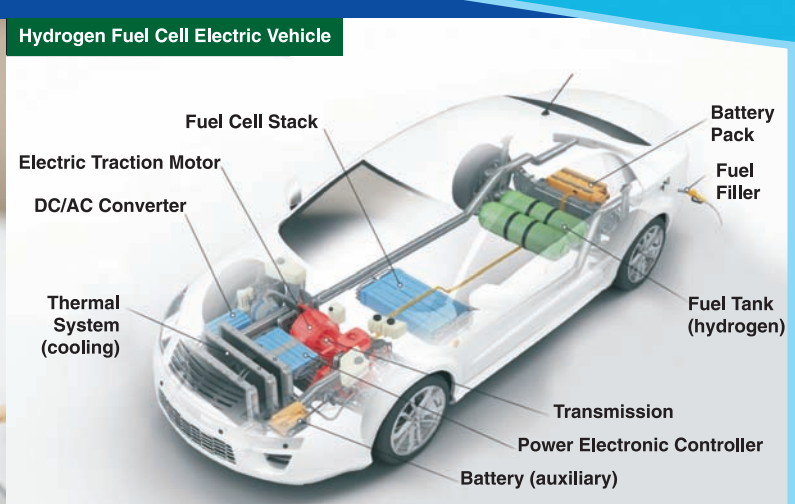
सत्यमेव जयते

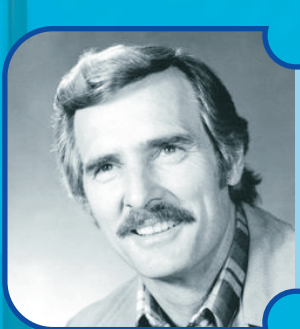
पेट्रोलियम एवं प्राकृतिक गैस मंत्रालय
Ministry of Petroleum & Natural Gas
Government of India

HydrogenTimes





FUEL CELL



If we had a hydrogen economy worldwide, every nation on earth could create its own energy source to support its economy, and the threat of war over diminishing resources would just evaporate.

Dennis Weaver

हरित ऊर्जा से आत्मनिर्भर भारत की ओर

A Quarterly Newsletter of Ministry of Petroleum & Natural Gas (MoP&NG) on Green Hydrogen Initiatives

October, 2023, Vol.-III

Green Hydrogen- Initiatives

Hydrogen Fuel Cell-powered (FCEV) buses were flagged-off by Honourable Minister of Petroleum and Natural Gas, Shri Hardeep Singh Puri

Tata Motors has recently unveiled two state-of-the-art R&D facilities for meeting the emerging needs of its sustainable mobility solutions using hydrogen as fuel at its R&D centre in Pune. This includes the engine test cell for development of hydrogen Internal Combustion Engine (ICE) and the necessary infrastructure for storage and dispensing of Hydrogen fuel for the fuel cell and H2 ICE vehicles.

The Indian Oil Corporation Limited (IOCL) has begun the process to set up its first green hydrogen generation plant in Panipat at 10 KTPA capacity. The new green Hydrogen Unit is proposed to be located within the vicinity of the Panipat Refinery Complex. The company intends to utilize green hydrogen produced using renewable power and integrate green hydrogen with the existing hydrogen network of the Panipat Refinery. The new unit will have a green hydrogen generation unit of 1,250 kg per hour capacity on 24×7 basis.

Oil India Ltd (OIL) is exploring setting up of green hydrogen valleys, or hubs, as a part of its energy-transition initiative. In line with its energy-transition goals, the company aims to replace diesel with natural gas across its group companies, like Numaligarh Refinery Ltd.

NRL has awarded a contract to M/S Greenko Zero C to set up a 300 kg/h (2.4 KTPA) green hydrogen plant at Numaligarh, with power consumption of 16-17 MWh. The technology provider of the alkaline water electrolyser is M/S John Cockerill, Belgium. The schedule completion date for the project is June 2025. The green H2 produced shall replace about 5 % of present grey H2 used in hydro-processing units of the refinery. NRL has planned to increase green hydrogen production to 20 KTPA by 2030. Out of these 20 KTPA , 10 KTPA through electrolyser route & 10 KTPA through CBG route

Interesting Facts about "Fuel Cell"

Sir William Grove first demonstrated the technology behind fuel cells in 1839. The gas battery, later named the fuel cell, reversed the well-understood principal of electrolysis to generate an electrical current. Grove's invention was largely a curiosity as the age was captivated by the horseless carriage and the large reserves of petroleum that were being discovered. Fuel cells remained in obscurity until 1960 when the upstart government agency, The National Aeronautic and Space Administration (NASA), began looking for a practical power source for extended missions to space. Through research and development sponsored by NASA and private industry, the fuel cell is poised to become a replacement for the internal combustion engine and redesign the utility industry by making energy cleaner, cheaper and portable.

> "I believe fuel cells could end the 100-year reign of the internal combustion engine."
> -William Clay Ford, Jr.

Principle of Fuel Cell

Fuel cells generate electricity through an electrochemical reaction, known as reverse electrolysis. 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.

There are five main types of fuel cells distinguished by the electrolyte used in the individual cells. i.e. Alkaline Fuel Cell (AFC), Polymer Electrolyte Membrane or Proton Exchange Membrane (PEM), Molten Carbonate (MCFC), Phosphoric Acid (PAFC) and the Solid Oxide Fuel Cell (SOFC).

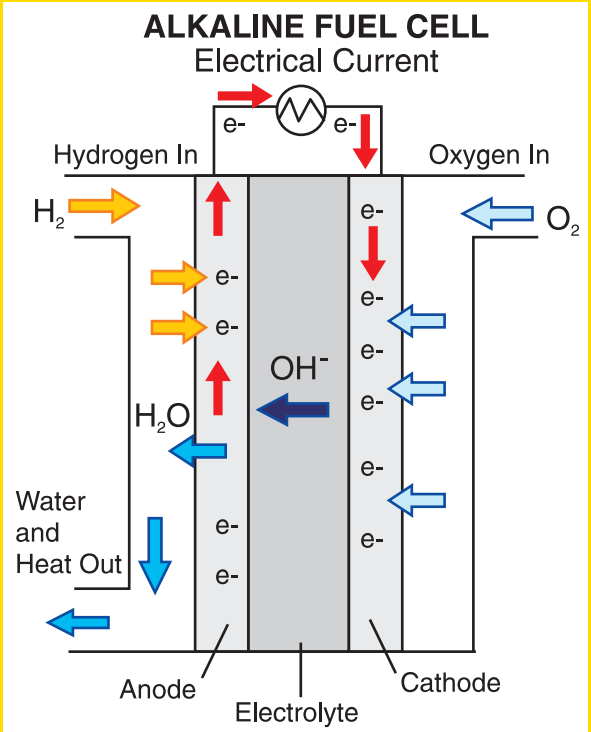
Application:

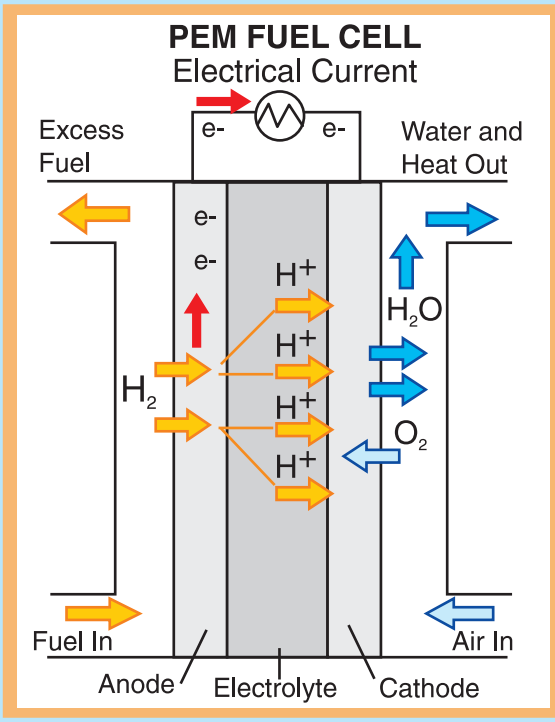
Hydrogen and fuel cells can be used in a broad range of applications. These range from powering buildings, cars, trucks, to portable electronic devices and backup power systems. Because fuel cells can be grid-independent, they're also an attractive option for critical load functions such as data centers, telecommunications towers, hospitals, emergency response systems, and even military applications for national defense.

ALKALINE FUEL CELL

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. AFCs are high-performance fuel cells due to the rate at which chemical reactions take place in the cell. They are also very efficient, reaching efficiencies of 60 percent in space applications.

The disadvantage of this fuel cell type is that it is easily poisoned by carbon dioxide (CO_2). In fact, even the small amount of CO_2 in the air can affect the cell's operation, making it necessary to purify both the hydrogen and oxygen used in the cell.





PROTON EXCHANGE MEMBRANE FUEL CELL

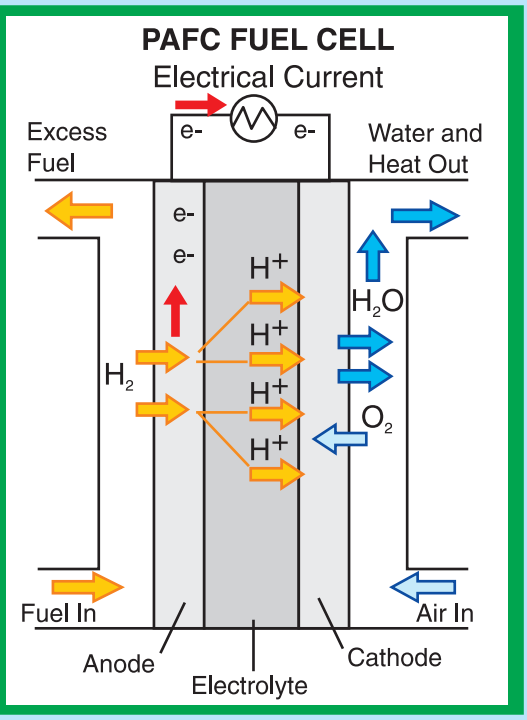
Polymer electrolyte membrane (PEM) fuel cells—also called proton exchange membrane fuel cells—deliver high power density and offer the advantages of low weight and volume, compared to other fuel cells. PEM fuel cells use a solid polymer as an electrolyte and porous carbon electrodes containing a platinum 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 on-board reformers.

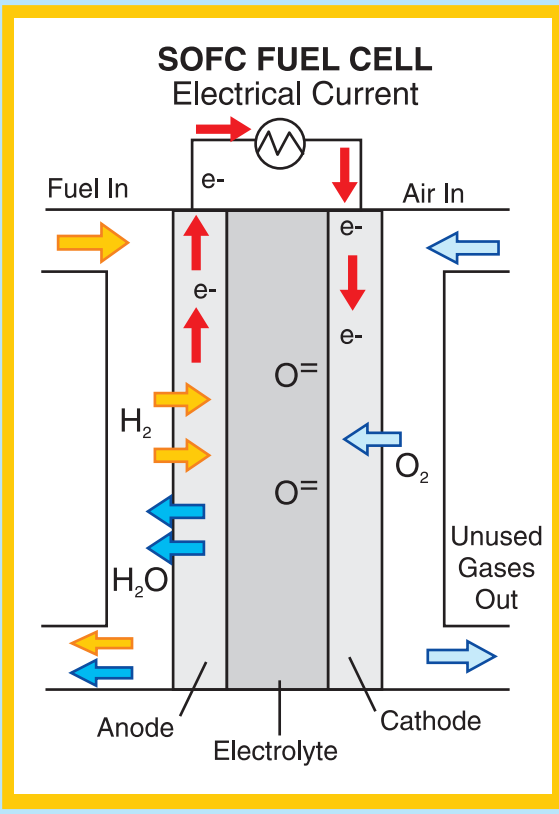
PEM fuel cells are used primarily for transportation applications and some stationary applications. Due to their fast start-up time, low sensitivity to orientation, and favorable power-to-weight ratio, PEM fuel cells are particularly suitable for use in passenger vehicles, such as cars and buses.

Interesting Facts about "Fuel Cell"

PHOSPHORIC ACID FUEL CELL

The phosphoric acid fuel cell (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, with over 200 units currently in use. 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 the reformate than PEM cells, which are easily "poisoned" by carbon monoxide. They are 85 percent efficient when used for the co-generation of electricity and heat, but less efficient at generating electricity alone (37 to 42 percent). 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. Like PEM fuel cells, PAFCs require an expensive platinum catalyst, which raises the cost of the fuel cell.





SOLID OXIDE FUEL CELL

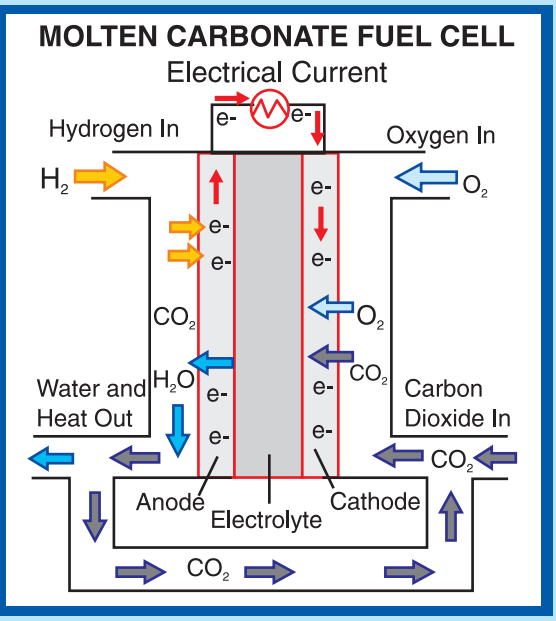
Solid oxide fuel cells (SOFCs) use a hard, non-porous ceramic compound as the electrolyte. Since the electrolyte is a solid, the cells do not have to be constructed in the plate-like configuration typical of other fuel cell types. SOFCs are expected to be around 50-60 percent efficient at converting fuel to electricity. In applications designed to capture and utilize the system's waste heat (co-generation), overall fuel use efficiencies could top 80-85 percent.

Solid oxide fuel cells operate at very high temperatures—around 1,000° C. High temperature operation removes the need for precious-metal catalyst, thereby reducing cost. SOFCs are also the most sulphur-resistant fuel cell type; they can tolerate several orders of magnitude more sulphur than other cell types. In addition, they are not poisoned by carbon monoxide (CO), which can even be used as fuel. This allows SOFCs to use gases made from coal.

MOLTEN CARBONATE FUEL CELL

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 and they operate at extremely high temperature of 650° C and above, 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 (PAFCs). Molten carbonate fuel cells can reach efficiencies approaching 60 percent, considerably higher than the 37-42 percent efficiencies of a phosphoric acid fuel cell plant. When the waste heat is captured and used, overall fuel efficiencies can be as high as 85 percent. 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.



Interesting Facts about "Fuel Cell"

Type	AFC (Alkaline)	PEMFC (Proton exchange)	SOFC (Solid oxide)	MCFC (Molten carbonate)	PAFC (Phosphoric acid)
Electrolyte	KOH	Membrane	$Y_2 O_3$ ZrO_2	Molten mixture	Liquid H_3PO_4
Conductible Ions	OH^-	H^+	O^{-2}	$CO3^{-2}$	H^+
Fuel	H2	H_2, CH_3OH	natural gas (CH_4, CO)	(H_2, CO)	H_2
Oxidant	Air	Air	Air	Air	Air
Catalyst	Pt/Ru	Pt	Ni	Ni	-
Operating temperature	65–220 °C	40–90 °C	600–1000 °C	~650° C	60-220
Theoretical voltage	1.18 V	1.18 V	1.13 V	-	-
System efficiency	60%–65%	60%–68%	80–85%	55-60%	37-42%
Application	Special ground and aerospace	Electric vehicle, submarine	Power station	Large-Scale Stationery Power generation	Distributed generation

Table 1. Comparison of characteristics of various Fuel Cells.

"Fuel cells create a better automobile that's 50 percent more energy-efficient overall and sustainable from energy and safety perspectives."
-Larry Burns

The first hydrogen fuel cell car was the 1966 GM Electrovan. But the first commercially produced hydrogen fuel cell automobile was the Hyundai Tucson FCEV which was introduced in 2013.

"Fuel cell vehicles run on clean-burning hydrogen and are three times more efficient than the traditional combustible engine."
-Albert Wynn

Benefits of Fuel Cell

Zero-Emission Power

Hydrogen fuel cells (HFCs) produce no harmful emissions, eliminating the costs associated with handling and storing toxic materials like battery acid or diesel fuel. In fact, when fueled with pure hydrogen, the only by-products are heat and water.

Robust Reliability

Hydrogen fuel cell technology has proven itself against tough conditions, including cold environments as low as -40 degrees F/C, weather environments like hurricanes, deserts, and winter storms, and even the hardworking business environments of material handling warehouses.

Improved Efficiency

Hydrogen fuel cells are generally between 40% to 60% energy efficient, according to the U.S. Department of Energy. This range compares to the typical internal combustion engine of a car, which is about 25% energy efficient.

Scalable

Modular fuel cell systems can be easily scaled up or down to meet the power needs of a wide range of applications, from small portable devices to large power plants. This scalability makes fuel cells a cost-effective and versatile solution for a variety of energy needs.

Lower Operational Costs

Compared to batteries and internal combustion generators, fuel cells save money. They eliminate the need to change, charge, and manage batteries, subsequently reducing labor, time, space, and peak power demands. The units run longer than lead-acid batteries and can be fueled in as little as three minutes, substantially reducing vehicle and personnel downtime.

Latest Developments

INDIA

India's first hydrogen fuel cell powered Bus–Honourable Minister of Petroleum and Natural Gas, Shri Hardeep Singh Puri flagged off India's first Green Hydrogen fuel cell bus in Delhi while informing that the government is planning to roll 15 additional buses soon in the National Capital region (NCR). "Hydrogen is deemed as the fuel for future with immense potential in helping India meet its decarbonisation targets and its global demand for hydrogen is expected to increase by four to seven times to 500-800 million tonnes by 2050," Shri Puri said at the launch. He said that the domestic demand is expected to increase by four times, from current 6 million tonnes at present to 25-28 MT by 2050. PSUs under the ministry shall be able to produce around 1 MMTPA of green hydrogen by 2030, "This green hydrogen powered bus is going to transform the face of city transport in the country. I shall be closely monitoring the project and wish you all the very best for successfully executing this project of national importance," he said.

SECI plan to set up 100-GW renewable energy capacity in next five years - The Solar Energy Corporation of India (SECI) aims to achieve a renewable energy capacity of 100 gigawatts (GW) in the next five years. Out of this, 10 GW will come from SECI's own or captive plants, while the remaining 80-90 GW will be developed by other companies. The renewable energy generated will be used for green hydrogen plants. SECI's own plants will require an investment of around Rs 55,000-60,000 crore, while the developer mode plants will be financed by the companies themselves.

REC to finance 2 green hydrogen, thermal project worth Rs. 40,000 crore - State-owned REC Ltd announced signing of initial pacts to finance two green hydrogen and a thermal power project in Odisha. REC has signed an MoU with Odisha Power Generation Corporation (OPGC) to finance Rs. 9,538 crore for the development of two units of thermal power project in Jharsuguda, Odisha, the company said in a statement. The collaboration will contribute significantly to the state's power generation capacity and energy infrastructure. Under partnership with ACME Group, REC will provide funding of Rs 16,000 crore for a green hydrogen and ammonia facility proposed at Gopalpur in the state. It has also entered into an MoU with Avaada Group, pledging Rs. 15,000 crore for a green hydrogen and ammonia facility at Gopalpur, REC said.

India & US have great potential to cooperate on green hydrogen: Shri Puri - India and the United States are important for each other, and have the gravitas and immense potential to cooperate on green hydrogen, said Shri Hardeep Singh Puri, Minister of Petroleum and Natural Gas. Speaking at Public Affairs Forum of India's 10th Annual Forum 2023 in New Delhi, he said India will be doing 20% ethanol blending by 2025. India and the US can work together on a plan to make ethanol from agricultural waste. "We are facing challenges on the energy front and we are working towards affordability, availability and sustainability. Green hydrogen, which is the fuel of the future, will succeed because India and the US individually will go after that," he said. The minister also said that India will be a 10 trillion dollar economy by 2030, but 50% of our GDP is in the external sector, which is the value of goods and services imported and exported and the value of remittances. This not only brings in businesses from the US but also from many other countries. There are many entrepreneurs who want to come to India.

Government to take all measures to make India competitive in hydrogen production: MNRE- The government will take all the measures to make India competitive in producing green hydrogen, Union Minister Shri R K Singh said. The minister for power, new and renewable energy made the remarks during a meeting with the green hydrogen developers. "With our single unified grid and large renewable capacity, India can produce the cheapest green hydrogen in the world. We will do everything in our power to make India competitive in producing green hydrogen and to achieve the targets set out in the National Green Hydrogen Mission (NGHM)," the minister was quoted as saying in the MNRE statement. The meeting aimed to understand the issues faced by the developers and how the government can help overcome these issues like SEZ policies, regulatory provisions for enabling dual connectivity, certain contractual conditions, and demand charges being levied by states among others. A presentation at the meeting indicated that for producing 1 million metric tonnes of hydrogen, 25 GW renewable energy is required while for producing 1 million metric tonnes of green ammonia, 5 GW renewable power is needed.

India, Saudi Arabia tie up for electrical interconnections, green hydrogen-India and Saudi Arabia inked an initial pact to collaborate in the field of electrical interconnections, green hydrogen and supply chains. The Memorandum of Understanding (MoU) aims to establish a general framework for cooperation between the two countries in the field of electrical interconnection and exchange of electricity during peak times and emergencies. Besides, both the countries aim for co-development of projects, co-production of green hydrogen and renewable energy, and also establishing secure, reliable and resilient supply chains of materials used in green/clean hydrogen and the renewable energy sector.

Need investments in research, innovation to reduce green hydrogen production cost: Ireda CMD- The cost of producing green hydrogen can be lowered through investments in research, development, and innovation, state-owned Ireda CMD Mr. Pradip Kumar Das has said. He made the remarks while addressing the A to Zero (Accelerate to Net Zero) ASEAN Summit in Kuala Lumpur in Malaysia, the Ministry of New and Renewable Energy (MNRE) said in a statement. "Das highlighted the importance of reducing the cost of Green Hydrogen through investments in research, development, and innovation. These investments aim to identify cost-effective methods for green hydrogen production," it added. He also advocated for leveraging

Latest Developments

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economies of scale in transportation (including pipeline and liquefaction) and storage facilities by establishing hydrogen hubs. These hubs would promote greater utilisation of infrastructure, further advancing the green hydrogen sector.

Round-the-clock renewable energy will cost Rs 6 per unit: MNRE- The Union Minister for Power and New and Renewable Energy Shri RK Singh said that round-the-clock renewable energy will cost just about Rs 6 per unit if green hydrogen is used for storage. Speaking at the Special Ministerial Session of the Fourth International Conference & Exhibition on Clean Energy in the national capital , Union Minister said that the cost of Green Hydrogen would be cheapest in India and that the Green Hydrogen would become a viable energy storage alternative. "Green hydrogen is cheaper than gas and battery energy storage systems. We have come up with a pilot bid for about 100 MW which we hope will establish the benchmark. Once we are able to use green hydrogen for our energy requirements, all supply chain issues such as availability of lithium-ion batteries will be resolved. We will make green hydrogen and use it as storage. The average price of power in the energy exchange has recently been Rs. 8 per unit, so if our cost for round-the-clock renewable energy comes to Rs. 6 per unit, we are in business. That is what the future is: renewables. The future is here, not far away," he said.

GLOBAL

France announces Eur700 million for hydrogen production funding in 2024- The French energy ministry has allocated Eur700 million ($737 million) for a support mechanism for hydrogen production in 2024. The funding allocation is part of a Eur10 billion package for ecological planning announced late Sept. 27, including Eur1.5 billion for nuclear in 2024. France is planning a call for 150 MW of electrolysis for hydrogen production in 2024, followed by 250 MW in 2025 and 600 MW in 2026, according to a consultation document published earlier in September. France is aiming for 6.5 GW of installed electrolyzer capacity by 2030, while the EU is targeting 10 million mt/year of green hydrogen production by that date, requiring over 80 GW of electrolysis.

ArcelorMittal and EDP Embrace Green Hydrogen in Steelmaking in Brazil- ArcelorMittal Tubarão and EDP are set to transform Brazil's steel making industry by assessing the feasibility of green hydrogen in the steel production process. Two industry giants, ArcelorMittal Tubarão and EDP, are forging a path to low-carbon steel production through green hydrogen, dive into their Memorandum of Understanding (MOU) and how it can lead to a greener, more sustainable steel making process. The MoU between ArcelorMittal Tubarão and EDP holds the promise of transforming Brazilian steel plants into sustainable, low-carbon facilities.

South Korea Unveils Eco-Friendly Green Hydrogen Facility- South Korea has introduced a hydrogen production facility that operates without emitting harmful greenhouse gases. The newly constructed facility, situated at the Seongnam Metropolitan Water Purification Plant, stands as a beacon of environmentally friendly hydrogen generation. Located in Seongnam-si, Gyeonggi Province, this facility leverages electricity from small hydroelectric power plants to generate hydrogen by splitting water molecules.

Turning Desert Sunshine into Green Hydrogen: China's Ambitious Clean Energy Transformation- In the vast expanse of China's Ningxia Hui autonomous region, an extraordinary transformation is underway. Rows of photovoltaic power panels, glistening in the sunlight, stretch as far as the eye can see across once-desertified land. This base, which has been a significant consumer of coal and emitter of carbon dioxide, is now at the forefront of China's mission to revolutionize its coal-to-chemical industry and embrace clean energy alternatives. This facility, connected to the national grid in June, represents just one facet of a demonstration project aimed at hydrogen production and carbon emissions reduction.

Egypt to Sign $16 Billion Green Hydrogen Investment Deal with Indian Firms- Egypt is on the verge of securing a game-changing investment deal worth $16 billion with two prominent Indian companies, ACME Group and Ocior Energy. The agreement with ACME Group, outlines plan to construct a vast green hydrogen industrial complex in Ain El-Sokhna. This complex will sprawl over an expansive 4.5 million sq. m of land and is set to become a major hub for green hydrogen production. Once operational, it is expected to generate a staggering 2.2 million tons of green hydrogen annually.

Kowa and Adani: Partners in Green Hydrogen- Adani Enterprises has forged a 50:50 joint venture with Japan's Kowa Company in Singapore. This landmark partnership aims to produce and market green ammonia, green hydrogen, and their derivatives marking a major stride in the global transition to clean energy. The joint venture agreement outlines the establishment of a Singapore-based company responsible for the sales and distribution of green ammonia, green hydrogen, and related products manufactured and supplied by the Adani Group. This collaboration signifies a crucial step towards expanding the presence of green hydrogen and ammonia in the market.

Latest Developments

GLOBAL

Future of Green Hydrogen Production Takes to the Sea- Professor Jihyun Hwang, from the Korea Institute of Energy Technology (KENTECH), unveiled the concept of offshore floating green hydrogen platforms, emphasizing its potential to enhance the utilization of offshore wind power plants and produce green hydrogen cost-effectively. The premise is simple yet revolutionary: build offshore floating green hydrogen platforms adjacent to offshore wind power plants, harness surplus electricity, and convert it into green hydrogen. This concept not only optimizes the use of offshore wind resources but also offers a cost-effective and scalable approach to green hydrogen production.

Germany's Augustus to Establish $500M Green Hydrogen Plant in Indonesia- Augustus Global Investment, a German firm, has unveiled plans to invest a whopping $500 million in a green hydrogen plant in Indonesia's Aceh province. The prime objective of this endeavor is the construction of a cutting-edge green hydrogen plant, expected to commence next year. This plant aims to leverage renewable energy sources to produce an impressive annual output capacity of 35,000 metric tons of green hydrogen, marking a pivotal step towards achieving clean and eco-friendly energy solutions.

Alstom Unveils Coradia Stream Hydrogen Train for Italy- Alstom, a leading manufacturer of railway transportation equipment, has announced that it has unveiled the Coradia Stream hydrogen train alongside the FNM group, a specialist in sustainable mobility in Lombardy. The train is expected to enter commercial service in Val Camonica between the end of 2024 and the beginning of 2025, on the non-electrified Brescia-Iseo-Edolo line, as part of the H2iseO project aimed at creating Italy's first hydrogen valley in the Brescia region.

Enapter AG and Tokyo Gas Collaboration Pioneers Hydrogen Refuelling in Japan- Japan, known for its commitment to decarbonization and embracing cutting-edge technologies, has taken another significant step towards its sustainable energy future with the establishment of the first commercial hydrogen refuelling station using AEM electrolysis in Asia. Enapter AG, a leading electrolyser manufacturer, collaborated with Tokyo Gas, one of Asia's largest gas companies, to deliver 30 AEM EL 2.1 electrolysers and 15 DRY 2.1 dryers for the "Senjyu" hydrogen refuelling station in Tokyo, Japan. This groundbreaking initiative aims to produce hydrogen on-site to refuel vehicles and drive Japan's ambitious efforts in promoting clean transportation and achieving environmental goals.

Isuzu and Honda Unveil Hydrogen-Powered Giga Fuel Cell Truck at Japan Mobility Show 2023-Isuzu Motors Limited and Honda are set to introduce the world to their revolutionary creation: the Isuzu Giga Fuel Cell heavy-duty truck. This hydrogen-powered truck is making its debut at the Japan Mobility Show 2023 and promises to reshape the landscape of heavy-duty transportation. The Isuzu Giga Fuel Cell is the product of extensive cooperation between two giants of the Japanese automotive industry. Isuzu, renowned for its robust heavy-duty trucks, provided the Giga platform, while Honda contributed its cutting-edge fuel-cell technology powered by hydrogen. Isuzu and Honda have strategically designed this system with the demands of long-haul, heavy-load operations in mind, making it an ideal choice for trucks that traverse great distances and endure extended hours of operation.

GREEN HYDROGEN DEFINITION IN INDIA

"Green Hydrogen" shall mean Hydrogen produced using renewable energy, including, but not limited to, production through electrolysis or conversion of biomass.

The non-biogenic greenhouse gas emissions arising from water treatment, electrolysis, gas purification and drying and compression of hydrogen shall not be greater than 2 Kg of CO_2 equivalent per Kg of Hydrogen, taken as an average over last 12- month period.

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