HYDROGEN

Hydrogen Production Processes

Hydrogen can be produced using several different processes. Thermochemical processes use heat and chemical reactions to release hydrogen from organic materials, such as fossil fuels and biomass, or from materials like water. Water (H_2O) can also be split into hydrogen (H_2) and oxygen (O_2) using electrolysis or solar energy. Microorganisms such as bacteria and algae can produce hydrogen through biological processes.

Biological Processes

Microbes such as bacteria and microalgae can produce hydrogen through biological reactions, using sunlight or organic matter. These technology pathways are in the research and development stage, with pilot demonstrations occurring, but in the long term have the potential for sustainable, low-carbon hydrogen production. Learn more about the following biological processes:

- **Microbial biomass conversion**
- **Photobiological**.

Hydrogen Production: Microbial Biomass Conversion

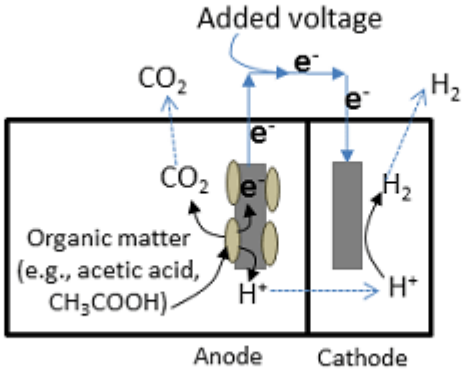
Microbial biomass conversion processes take advantage of the ability of microorganisms to consume and digest biomass and release hydrogen. Depending on the pathway, this research could result in commercial-scale systems in the mid- to long-term timeframe.

How Does it Work?

In fermentation-based systems, microorganisms, such as bacteria, break down organic matter to produce hydrogen. The organic matter can be refined sugars, raw biomass sources such as corn stover, and even wastewater. Because no light is required, these methods are sometimes called "dark fermentation" methods.

In direct hydrogen fermentation, the microbes produce the hydrogen themselves. These microbes can break down complex molecules through many different pathways, and the byproducts of some of the pathways can be combined by enzymes to produce hydrogen. Researchers are studying how to make fermentation systems produce hydrogen faster (improving the rate) and produce more hydrogen from the same amount of organic matter (increasing the yield).

Microbial electrolysis cells (MECs) are devices that harness the energy and protons produced by microbes breaking down organic matter, combined with an additional small electric current, to produce hydrogen. This technology is very new, and researchers are working on improving many aspects of the system, from finding lower-cost materials to identifying the most effective type of microbes to use.



Why Is This Pathway Being Considered?

Biomass is an abundant domestic resource, and many microbes have evolved to efficiently break down biomass to produce hydrogen and other products. Fermentation has already been used as an industrial technology to generate biofuels and other products, and many of the challenges to scaling up systems have been addressed for different products, allowing hydrogen researchers to focus on the challenges unique to hydrogen production. MEC-based systems have the potential to produce hydrogen from resources that otherwise can't be used for fuel production and could reduce the large amount of energy normally needed for wastewater treatment while producing a valuable fuel in the form of hydrogen. These two pathways can be combined to maximize the hydrogen yield from the starting biomass feedstock.

Research Focuses on Overcoming Challenges

Research in microbial biomass conversion for hydrogen production has progressed in recent years, but U.S. Department of Energy efforts are working to address a number of challenges. Key areas of research and development include:

- Improving the rates and yields of hydrogen production from fermentation processes through a number of methods such as microbial strain improvements, reactor system optimization, and identifying feedstock sources and processing methods with the highest yields.
- Developing MEC systems that can be scaled up to commercially relevant sizes while maintaining the production rates and system efficiencies seen at the bench scale and minimizing the costs of the reactor components.

Direct Solar Water Splitting Processes

Direct solar water splitting, or photolytic, processes use light energy to split water into hydrogen and oxygen. These processes are currently in various early stages of research but offer long-term potential for sustainable hydrogen production with low environmental impact. Learn more about the following solar water splitting processes:

- **Photoelectrochemical (PEC)**
- **Photobiological**.

Electrolytic Processes

Electrolyzers use electricity to split water into hydrogen and oxygen. This technology is well developed and available commercially, and systems that can efficiently use intermittent renewable power are being developed. Learn more

Thermochemical Processes

Some thermal processes use the energy in various resources, such as natural gas, coal, or biomass, to release hydrogen from their molecular structure. In other processes, heat, in combination with closed-chemical cycles, produces hydrogen from feedstocks such as water. Learn more about the following thermochemical processes:

- **Natural gas reforming** (also called steam methane reforming or SMR)
- **Biomass gasification**
- **Biomass-derived liquid reforming**
- **Solar thermochemical hydrogen (STCH)**.

- about **electrolysis**.

New study confirms €1 trillion Africa's extraordinary green hydrogen potential

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· European Investment Bank, International Solar Alliance and the African Union unveil study into Africa's green hydrogen potential, with the support of the Government of Mauritania, Hy Deal and UCLG Africa Analysis highlights benefits of harnessing solar power to create green hydrogen in four African hubs: Mauritania, Morocco, southern Africa and Egypt Green hydrogen is economically viable at EUR 2/kg and can accelerate low-carbon economic growth across continent and reduce emissions by 40%

Africa can secure access to clean and sustainable energy on the continent and become a global energy player through green hydrogen exports Harnessing Africa's solar energy to produce 50 million tons of green hydrogen a year by 2035 can help secure global energy supply, create jobs, decarbonize heavy industry, enhance global competitiveness and transform access to clean water and sustainable energy. The analysis has been commissioned by the

European Investment Bank, the International Solar Alliance and the African Union, with the support of the Government of Mauritania, Hy Deal and UCLG Africa, the "Africa's Extraordinary Green Hydrogen Potential" report represents the first detailed research of the feasible development of green hydrogen across the continent. The new study combines analysis of 1 / 4 investment opportunities focusing on three hubs: Mauritania - Morocco, southern Africa and Egypt with a roadmap of technical, economic, environmental and financial solutions to unlock commercial development. "Africa's has the best solar energy in the world and transforming solar power into green hydrogen can strengthen energy security, cut emissions and pollution and decarbonise industry and transport. The European Investment Bank

is working with partners across Africa and around the world to harness its renewable energy potential to produce low-cost green hydrogen at scale. The Africa's Extraordinary Green Hydrogen Potential report shows concrete opportunities to transform access to green energy and clean water across the continent and beyond." said Abdisalam Ould Mohamed Salah, Minister of Energy of the Republic of Mauritania, "Africa has the best renewable energy in the world and scaling up production of green hydrogen can transform access to low-cost electricity and clean water. Unlocking Africa's green hydrogen potential will require close cooperation between public, private and financial partners. The new "Africa's Extraordinary Green Hydrogen Potential" study outlines what can be achieved and what needs to be done. The European Investment Bank is pleased to work with African and international partners to enable large scale green hydrogen to become a reality." said Ambroise Fayolle, Vice President of the European Investment Bank. "Solar photovoltaic technology has provided us with the cheapest electricity. It will cost below €2 per kg in several African countries by 2030, much lower than the current mass assumption of €5 and a stark contrast to the $60-70 paid for an oil barrel. Thanks to this low-cost electricity and decreasing electrolyser costs, the next step is providing access to a clean fuel, cheaper than all the current fossil fuels. It will enable us to decarbonise the power sector and most hard-to-abate sectors - fertilisers, steel manufacturing, and refineries." said Dr Ajay Mathur, Director General, International Solar Alliance. "As the global energy and climate crises unfold, mass-scale competitive green hydrogen is ready to provide energy security, affordability and decarbonization. Integrated hydrogen hubs bringing together upstream, midstream and upstream players based on long-term off-take contracts are building powerful business models. Pioneering African countries such as Mauritania are showing the way, proving that Africa can help the world with green hydrogen – ensuring for itself a future of industrial development, fast and clean growth for all" says Thierry Lepercq, President of Hy Deal. The study was previewed at the Mauritania Pavilion at COP 27 in Sharm el Sheikh by Abdisalam Ould Mohamed Salah, Minister of Energy of the Republic of Mauritania, Ambroise Fayolle, Vice President of the European Investment Bank, Dr Ajay Mathur, Director General, International Solar Alliance, Jean-Pierre Elong Mbassi, Secretary General of UCLG Africa and Hakima el Haité former Minister of Environment of Morocco and Thierry Lepercq, President of HyDeal. Government leaders, ministers, international finance, business partners and civil society from across Africa attended the unveiling event. The report was formally handed over to partners on December 20th. Scaling up green hydrogen production to transform access to low-cost energy The comprehensive analysis carried out in recent weeks by international consultancy CVA suggests that large scale green hydrogen investment can accelerate decarbonisation by enabling large scale African energy users, such as fertilizer and steel producers, to use green hydrogen. The research is enhanced by CVA's unique strategic partnership with energy partners across Africa, Europe and around the world. The study highlights that solar powers green hydrogen is economically viable and can be produced at less than EUR 2 per kilogramme, cheaper than traditional fossil fuel energy, and cater both for local energy demand and allow green hydrogen to be exported to global markets. This is equivalent to energy costs of USD 60 a barrel. Roadmap for green hydrogen commercialisation across Africa **The research suggests three requirements to enable 50 million tons of green hydrogen to be produced in Africa by 2035:**

- **National planning, regulation and incentive schemes need to mobilise private sector investment.**
- **Pilot projects need to show successful green hydrogen generation, storage, distribution and use at both demonstration and commercial scale.**
- **Market-based partnerships are needed to enable mass-scale domestic and international off-take and demand for green hydrogen, and increase cooperation to design, finance, build and operate green hydrogen production, storage and distribution infrastructure. EUR 1-trillion green hydrogen investment can deliver the equivalent of more than one third of Africa's current energy consumption, boost GDP, improve clean water supply and empower communities. The new study outlines how production and transmission of green hydrogen can lead to a EUR 1-trillion investment yielding 7 exajoules of energy (versus a consumption in Africa of 19.9 exajoules in 2021) and a correlative massive increase in GDP, creating hundreds of thousands of permanent and skilled jobs across Africa. Large scale green hydrogen investment will transform supply of clean water in areas regularly impacted by drought and chronic water shortages and will help empower communities. Decarbonising Africa's heavy industry**

The new analysis estimates that green hydrogen investment could reduce carbon emissions in Africa by 40%, replacing 500 million tons of CO2 a year. Enabling Africa to be a global green hydrogen

powerhouse According to the study large scale green hydrogen generation will enable Africa to supply 25 million tons of
green hydrogen to global energy markets, equivalent to 15% of current gas used in the European Union. The new analysis will be followed by in-depth research of local green hydrogen investment potential, regulatory requirements and changing demand in the coming months. See the briefing document Background information EIB Global is the EIB Group's specialised arm dedicated to increasing the impact of international partnerships and development finance. EIB Global is designed to foster strong, focused partnership within Team Europe, alongside fellow development finance institutions, and civil society. EIB Global brings the Group closer to local people, companies and institutions through our offices across the world.
https://twitter.com/EIBGlobal
https://www.linkedin.com/company/eib-global/
The International Solar Alliance (ISA) is an alliance of 121 signatory countries based in Gurugram(India)
dedicated to fostering the development of solar energy with a specific focus on the developing world, to help address energy security and climate change. Hy Deal is the initiator of Hy Deal España, a joint venture between solar development, gas transmission, steel and fertilizer companies, building Europe's largest integrated green hydrogen hub. It is based on market based off-take contracts of 6.6 million tons of hydrogen over 20 years in Northern Spain, with production starting in 2025. Hy Deal is also collaborating with the Government of Mauritania on the development of