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Potential of Renewable Green Hydrogen Production in Shores of Countries (Offshore & Onshore)

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Global warming is the result of increase in fossil and non-renewable fuel consumptions.
Several oil & gas countries have started renewable energy and green gas production programs.

Almost all seashore countries have the potential to be a sector in renewable energy and green hydrogen gas production.

ABSTRACT
The phenomena of industrialization and transportation greenhouse gases production lead to increase in global warming. The currently increase in the global warming caused global environmental protection experts and decision-makers in the United Nations Organization to encourage countries to define and execute their action plans to reduce the global warming. The action plans comprise of decreasing the consumption of fossil fuels and/or to substitute them with renewable energies and gases. The ultimate goal is to reach net zero emission GHG's and prevent climate change environmental impacts in the worldwide in the third millennium AD.

KEY WORDS
Global warming, Green hydrogen gas, Climate change environmental impacts, Net zero emission GHG's, Renewable energy, Technology .Technology transfer, Decarbonization, PTX (P2X) ,Offshore & Onshore , Energy transition

INTRODUCTION
As usual, oil & gas producing, and industrial countries are among the top ten greenhouse gas producing countries in the world due to its huge oil and gas reserves or its consumption.
Therefore, these countries, in addition to having huge resources and consumption of petroleum and fossil gas, have potential to spread warming global and climate change impact then should invest and implement technological substitution plans to become a regional hub in renewable energies and green gases production in the worldwide. Of course, there may be few challenges in this approach energy transition in this new field of energy.

Currently, most of the countries that have: A) huge oil and gas hydrocarbon resources B) offshore and onshore areas C) natural sources of renewable energies such as solar and wind, have started long-term plans for large-scale decarbonization P2X projects in the form of green hydrogen gas production by electrolysis technology with the perspective of the years 2030, 2040 and 2050.

HYDROGEN GAS
Hydrogen gas (H2) can be considered as a completely clean gaseous fuel after natural gas (CH4) with a suitable heating value. Based on the type of feedstock, there are few types of hydrogen gas as follows:

- Blue hydrogen (based on fossil methane feed)
- Brown hydrogen (based on coal methane feed)
- Green hydrogen (based on bio methane or electrolyzed water feed).

HYDROGEN PROCESS PRODUCTION & HEATING VALUE

Hydrogen gas is produced in various ways in the industry. For example, in non-renewable energy industries, it is mainly obtained from reforming natural gas process (1), and in non-renewable energy industries, it is produced through the electrolysis process of water (2) in offshore & onshore of the seas and oceans:

- steam methane reforming (SMR) : CH4 + H2O + Q = 3H2 (blue or gray)+ CO (1)
- Electrolysis of water : 2H2O + DC electricity = 2H2 (green) + O2 (2)

Gaseous Fuels @ 32 F and 1 atm	Btu/lb (HHV)
Natural gas (Methane)	22,453
Hydrogen	61,127
Liquefied petroleum gas (LPG)	21,561
Conventional gasoline	20,007
Low-sulfur diesel	19,594
Liquefied natural gas (LNG)	23,734

Table 1—Heating values of Hydrogen gas and fuels (https://chemeng.queensu.ca/courses/CHEE332/files/ethanol_heating-values.pdf, 2022)

On a BTU/lb basis, Hydrogen has about 2.5 times the energy density of methane. So, if you burn one pound of hydrogen vs one pound of natural gas (Methane), you will get 2.5 times the energy (Table 1).

WATER ELECTROLYSIS TO PRODUCE GREEN HYDROGEN GAS

Today, one of the most important global decarbonization projects to deal with climate change is the water electrolysis project with the help of renewable electricity (such as: wind/solar/...) in the vicinity of sea water to produce green hydrogen fuel and renewable energy (Figure 1).

- Water Electrolysis : 2H2O + Renewable electricity = 2H2 (green) + O2

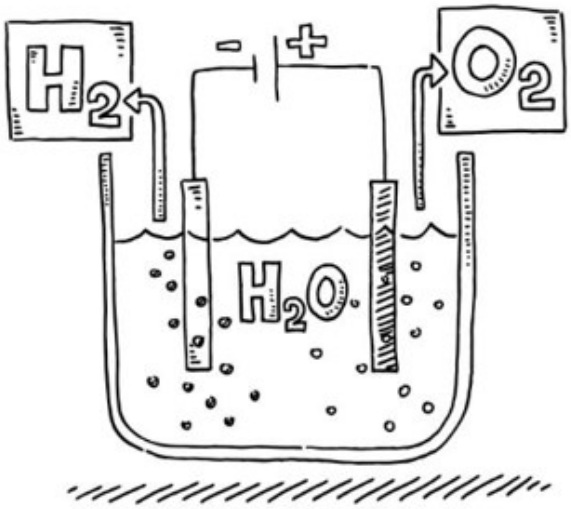

Figure 1 – Water electrolysis

DIRECT CURRENT ELECTRICITY NEEDED TO WATER ELECTROLYSIS

The water electrolysis process requires direct current (DC) electricity. Therefore, wind/ solar/...renewable electricity generation sources are considered the best electricity supply options for the water electrolysis process. Of course, if alternative current (AC) is also available, it can be converted to direct current with an inverter. Therefore, if there are huge water resources (such as seas) in the vicinity of solar or wind renewable electric energy production sources on the coasts of the sea or in the seas, the technological process will be easily applicable (Figure 2).

Figure 2 – Supply chain of green hydrogen production from water electrolysis by renewable electricity (Ref.:Azocleantech.com, 2022)

Of course, in this regard, the appropriate placement of these God-given renewable resources in terms of sun intensity/wind speed and proximity to the possible pipeline transmission lines (to transfer hydrogen gas to the source of consumption) can all be considered as part of the main parameters of the challenges and opportunities of conducting electrolysis technology in the offshore or onshore, which requires detailed engineering studies.

GREEN HYDROGEN PRODUCTION : CURRENT STATE AND OUTLOOK IN COUNTRIES

This section of the article compares the current and future situation of green hydrogen production by electrolysis technology in the offshore and onshore sectors in different countries (Figure 4).

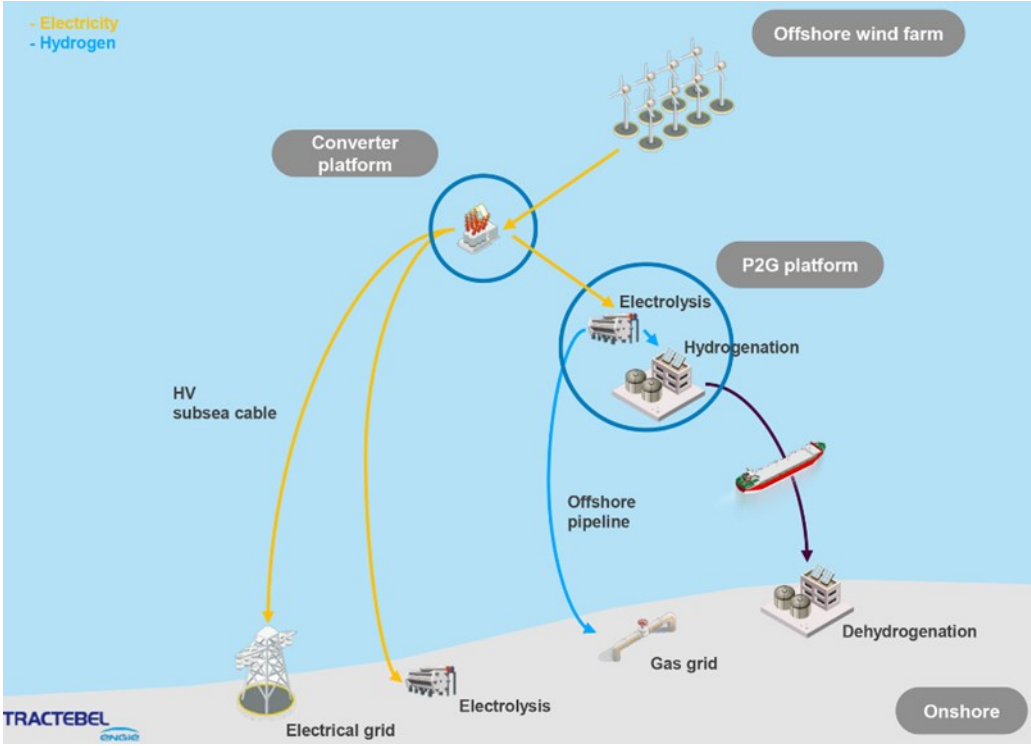

Figure 4.Supply chain of green hydrogen and renewable electricity in offshore & onshore (Reference: https://tractebel-engie.com/en , 2022)

OMAN

Oman is planning to build one of the largest green hydrogen plants in the world in a move to make the oil-producing nation a leader in renewable energy technology.Construction is scheduled to start in 2028 in Al Wusta governorate on the Arabian Sea. It will be built in stages, with the aim to be at full capacity by 2038, powered by 25 gigawatts of wind and solar energy.The consortium of companies behind the $30bn (£21bn) project includes the state-owned oil and gas company OQ, the Hong Kong-based renewable hydrogen developer InterContinental Energy and the Kuwait-based energy investor Enertech.Once online, the plant will use renewable energy to split water in an electrolyser to produce green hydrogen, which is able to replace fossil fuels without producing carbon emissions. Most will be exported to Europe and Asia, said Alicia Eastman, the co-founder and president of InterContinental Energy, either as hydrogen or converted into green ammonia, which is easier to ship and store. The facility aims to produce 1.8m tonnes of green hydrogen and up to 10m tonnes of green ammonia a year.

Oman currently relies heavily on fossil fuels, generating up to 85% of its GDP from oil and gas, but its fossil fuel reserves are dwindling and becoming increasingly costly to extract. In December 2020, the country published its Oman Vision 2040 strategy, a plan to diversify the economy away from fossil fuels and increase investment in renewables.Green hydrogen could play an important role, said Eastman, thanks to the Oman's combination of plentiful daytime sun and strong winds at night. "Oman is one of the places in the world that I've called the 'future renewable superpowers'," said Michael Liebreich, the founder of BloombergNEF, "because what you really want [to produce green hydrogen] is very cheap solar and very cheap wind."While electrification is the most efficient way of decarbonising most sectors, it's limited when it comes to energy-intensive industries such as steel, chemicals, aviation and shipping. Green hydrogen will be vital to help fill these gaps, said the International Energy Agency in its report published this week, which called for an end to fossil fuel investments if governments are serious about climate commitments.A wave of net zero-emissions pledges has already led to a slew of hydrogen strategies, including from the European Commission in 2020, which predicted the share of hydrogen in the EU's energy mix would rise from 2% to 14% by 2050.(1)

CHINA

China's Sinopec International Petroleum Service Corporation is building the world's biggest plant for the production of hydrogen from renewables The factory will be powered by a 300 MW #photovoltaic plant is expected to be put into operation 2023 Sinopec plans to produce 20,000 tons of green hydrogen a year

once the facility is completed while the expected reduction of #co2emissions about 485,000 tons a year The plant located in the northwestern region of #xinjiang will cost about USD 470.8 million to build with #solarpanels covering an area of over 630 hectares. The cost of hydrogen production there will be only USD 2.67 /kg according to media SINOPEC announced that the project would cover the whole process of #greenhydrogen production and utilization from solar power generation electrolytic production storage and transportation It will include 300 MW solar power plant a #waterelectrolysis hydrogen production plant hydrogen storage tanks, and a hydrogen pipeline #greenhydrogen will replace natural gas based hydrogen used at Sinopec's #Taheoilrefinery Sinopec estimates that in the future the whole #petroleumindustry will create a market worth more than USD 14.8 billion by replacing #greyhydrogen which is produced using #electricity generated from #fossilfuels #cop27 #cop26.(2)

BRAZIL

Brazilian chemical maker Unigel on Monday announced plans to build a green hydrogen plant in the northeastern state of Bahia, with an initial investment of $120 million and the goal of making it one of the largest of its kind in the world.The plant is expected to start operations by the end of 2023, Unigel said in a statement. The first phase of the project foresees a production capacity of 10,000 tonnes of green hydrogen and 60,000 tonnes of green ammonia per year.

The electrolysis process for hydrogen production at the Bahia plant will be carried out in equipment supplied by Germany's ThyssenKrupp Nucera, controlled by Thyssenkrupp AG (TKAG.DE), totaling 60 megawatts.

- Green hydrogen and ammonia produced in the industrial city of Camacari will be offered to customers looking to decarbonize their operations, Unigel said.

Earlier this year, Fortescue Future Industries signed a pre-contract to develop a plant in Pecem while Shell (SHEL.L) announced a project in Rio de Janeiro's Acu port. Unigel said that in a second phase of its Camacari project, seen happening in 2025, it expects to quadruple the output of green hydrogen and ammonia. (3)

UAE

Abu Dhabi ports is planning 2GW green hydrogen to ammonia project. (4)

IRELAND

Floating wind and hydrogen | Project Dylan, a world leader. In the aftermath of two strategic sessions Holistic Network Design and Floating wind for the Celtic Sea, the community may welcome and update on Floating Wind and Hydrogen a devolved government commitment to net zero and Wales Hydrogen Pathway. (5)

SOUTH KOREA

Corio and TotalEnergies' floating wind farm, called Ulsan Gray Whale 3, is planned to be built around 60 to 70 kilometres from Onsan Port in Ulsan. #floatingwind #hydrogen #cluster #apac #ulsan #hyundai #hydrogeneconomy #shipping #vessels .#netzero Join the experts group: https://bit.ly/3hbRE4A Corio, TotalEnergies Award FEED Contract for 504 MW Floating Wind Farm in South. (6)

SAUDI ARABIA

The plant is being built by Pennsylvanian company Air Products, which agreed a deal for the scheme in July 2020. This envisaged a system that will use some 4GW of wind and solar electricity to produce more than 650 tonnes of hydrogen a day from 120 Thyssenkrupp electrolysers, each about 40m long.The hydrogen will be made in the form of ammonia, which is easier to transport than hydrogen in its liquid form.So far, site preparation work has been in progress, and this will give way to building in the next few days.

The announcement was made by Peter Terium, the chief executive of Enowa, which is Neom's energy, water and hydrogen subsidiary. He told the Bloomberg news agency that the plant would enable Saudi Arabia to compete with China, South Korea, Europe and the US, all of which are ramping up their own hydrogen sectors.Alongside the green hydrogen market, state oil producer Saudi Aramco is developing blue hydrogen production, with the help of Air Products and Saudi utility ACWA Power International. Blue hydrogen is made from natural gas.The Neom economic zone is located in Saudi Arabia's northwest, on the coasts of the Red Sea and Gulf of Aqaba. As well as advanced manufacturing, it will be home to The Line, a car-free, zero-carbon city with 1 million inhabitants and no roads, laid out as a 170km-long belt with services and transport infrastructure built underground. (7)

SCOTLAND

Developers can apply for the rights to build small-scale innovative offshore wind projects, of less than 100MW, and projects which will provide green electricity to oil and gas infrastructure to reduce their carbon emissions. Crown Estate Scotland's final leasing documents have been optimised to support early project development and reflect many of the comments and suggestions from potential applicants, who were asked for feedback earlier this year. These include extending Option Periods from five to seven years and doubling Lease Periods from 25 to 50 years for electrification projects.(8)

GERMANY

HH2E and MET Group are building one of the largest plan €1bn German green hydrogen project #greenhydrogen production facilities in #europe It will operate with an input power of 100 MW (6,000 tons/y of H2) by 2025 and 1 GW (60,000 tons/y of H2) by 2030. #greenhydrogen is essential for our energy transition, security of supply and energy sovereignty. (9)

NAMIBIA

Hydrogen megaproject Progress on $10bn Namibian green hydrogen project.The project will produce approximately 350,000 tonnes of green hydrogen per year, with 5-6GW of renewable generation capacity paired with 3GW of electrolysis capacity. (10)

THE NETHERLANDS

The technology can be used to transport hydrogen, CO2, ammonia and water, where steel solutions suffer from embrittlement and corrosion. As TCP is a flexible pipe, it can be installed offshore easily and quickly, using the same methods as currently used for array cables, #Netherlands has announced new plans to develop a national transport network for #hydrogen The network will connect #ports large industrial clusters in the country and storage locations for hydrogen. Connections with #Germany #Belgium will also be established. The network will be developed and operated by Gasunie Dutch Minister for Climate and Energy Rob Jetten also said he would look into whether the company can fulfil the role of #offshoregrid operator, given the planned growth of hydrogen production in the #northsea Around 85% of the national hydrogen network will consist of repurposed natural gas pipelines, which the International Renewable Energy Agency (IRENA) recently estimated could cost 65-94% less than building new hydrogen pipes. The pipelines are expected to become available as less natural gas is transported in the coming years. Netherlands is preparing to shut down the #groningen gas field in late 2023 or early 2024. (11, 12)

PAKISTAN

#Pakistan has granted "comprehensive permission" for the construction of a 400MW #greenhydrogen project that would be powered by 500MW of #windenergy and 700MW of #solarenergy backed up by a battery. (13)

ISLAND

Well said but sometimes the things we seek are already there under our noses. Wind energy is a good contributor but not the solution. Some existing technology developers hold much of the answers to the energy crisis and are ready to contribute today. However due to the small nature of these companies, and lack of resources they find it difficult to rise above the noise & bureaucracy. SEA WAVE ENERGY LIMITED is very serious about energy and can act now! Using the data collected by EMECs Datawell Waverider Buoy, one Waveline Magnet system would be rated at over 100MWh of mechanical power, with the annual equivalent exceeding 140,000MWh or 3,596,000 kg's of Green Hydrogen, at a cost of 0.0251 € / kWh (25.06€/MWh). (14)

UNITED STATES OF AMERICA

Maine, offshore wind process begins through BOEM and hydrogen hub announced by Governor Hochul. Maine and Rhode Island have signed on to a New York-led multi-state agreement, joining with Connecticut, Massachusetts and New Jersey to develop a proposal to become one of at least four regional clean hydrogen hubs designated through the federal Regional Clean Hydrogen Hubs program included in the bipartisan Infrastructure Investment and Jobs Act. Don't wait for the trade press, stay informed through me and with the over 2500 strong community of experts. (15)

CANADA

With abundant offshore wind resources, plentiful storage grade salt formations, and easy access to large European energy markets, Nova Scotia is well suited for large scale green hydrogen production. The declining cost curve of offshore wind power and falling electrolyser prices means large scale production of green fuels will soon be cost competitive with hydrocarbons, allowing Nova Scotia to become a major global player in clean en-

AUSTRALIA

The recent announcement of six further offshore wind arrays represents a global market opportunity. Stay informed with the over 2500 strong. (17)

EGYPT

Alfanar Construction (KSA) is sharing glimpses of the green hydrogen MoU signing ceremony in Egypt last week. Witnessed by His Excellency Mostafa Madbouly, Prime Minister of Egypt Mohamed Shaker, Minister of Electricity and Renewable Energy, Hala H. Elsaid Minister of Planning & Economic Development, along with Saudi officials, Faisal A.Alyemni Deputy Minister of Investment, and Mazeed ben Mohammed Al-Hoishan, the Saudi Consul to Egypt. Represented by Alfanar was Mr. Sabah Almutlaq Chairman of Alfanar Global Development Jamal Wadi MD Alfanar Global Development, and Amer Al Ajmi EVP Sales & Marketing at Alfanar Construction. (18)

CHALLENGES & OPPORTUNITIES

In addition to the benefits and positive effects of implementation PTX (P2X) projects to run the decarbonization net zero plans and combat climate change for the current and future

conditions for all countries of the world and the world's environment, there will be challenges such as:

The cost of investing in the production of renewable products

Determining best locations for the construction of renewable electricity production plants especially next to the enough seawater for operation of electrolysis units.

Table 2 shows the amount of investment made by some countries in the Middle East and other countries in the field of green hydrogen and green ammonia production by PTX projects in 2022.

Table 2—Selected P2X Green Hydrogen Projects & Plants in Middle East Area and Other countries (2022)

Row	Country	Investment	GH2/GNH3	Powered by renewable elect.	Deadline	Remarks
1	Oman	$30bn	GH2+GNH3	25GW	2028	One of largest GH2 Plant
2	Australia	$36bn	GH2+GNH3	26GW(wind)	2028(1st.phase)	One of largest GH2 Plant
3	Brazil	-	600kt/y	3.4GW	2026	
4	China	$470m	GH2	300MW	2023	Reduction of 485kt/y CO2 emissions
5	Brazil	$120m	10kt/y GH2 60kt/y GN3	-	2023(1st.phase)	
6	UAE	$10.28bn	GH2+GNH3	4GW		
7	Qatar	$1bn	GNH3	-		
8	Saudi Arabia	$10.5bn	GH2+GNH3	-		
9	Egypt	$63.8bn	GH2	Solar + Wind		
10	Namibia	$10bn	350kt/y GH2	3GW		
11	ME nations	$150bn	GH2+GNH3	-		MEED Report August 2022

CONCLUSION

Considering:

- The control of global warming
- Climate change control by energy transition
- Decreasing trend of non-renewable fossil fuel sources and their becoming more expensive
- Decarbonization
- Net zero emission
- Energy transition

are necessary to go towards the use of clean, renewable fuels substitution and energies in all parts of the world to mitigate and prevent the release of more greenhouse gases. According to the global warming and relevant international conventions of the United Nations (UNFCCC) in this subject, therefore, the need to develop and use P2X technologies in the offshore and onshore areas adjacent to the sea waters will definitely play a valuable and key role in energy transition for the world especially using electrolysis technology.

There are also challenges and opportunities in PTX (P2X) projects, but currently only in the region of Middle East, there are more than 50 projects in this subject constructed or under construction, amounting to 150 billion dollars of investment in which It should be noted that some of these projects are considered to be among the largest PTX technology projects of green hydrogen in the worldwide in 2022.

APPENDIX

Appendix A: Heat Values of Various Fuels

The heat value of a fuel is the amount of heat released during its combustion. Also referred to as energy or calorific value, heat value is a measure of a fuel's energy density, and is expressed in energy (joules) per specified amount (e.g. kilograms).

Appendix B: How much hydrogen is produced from 1kg of water electrolysis?

1 liter of water = 1 kg of water. Molar mass of water = 18g, of which H2 = 2g, O = 16g. So 2/18 = 1/9 = 11%. So one liter of water gives 110g of hydrogen gas, which is about 1.3 cubic meters of gas at normal temperature and pressure.

	Heat value
Hydrogen (H_2)	120-142 MJ/kg
Methane (CH_4)	50-55 MJ/kg
Methanol (CH_3OH)	22.7 MJ/kg
Dimethyl ether - DME (CH_3OCH_3)	29 MJ/kg
Petrol/gasoline	44-46 MJ/kg
Diesel fuel	42-46 MJ/kg
Crude oil	42-47 MJ/kg
Liquefied petroleum gas (LPG)	46-51 MJ/kg
Natural gas	42-55 MJ/kg
Hard black coal (IEA definition)	>23.9 MJ/kg
Hard black coal (Australia & Canada)	c. 25 MJ/kg
Sub-bituminous coal (IEA definition)	17.4-23.9 MJ/kg
Sub-bituminous coal (Australia & Canada)	c. 18 MJ/kg
Lignite/brown coal (IEA definition)	<17.4 MJ/kg
Lignite/brown coal (Australia, electricity)	c. 10 MJ/kg
Firewood (dry)	16 MJ/kg
Natural uranium, in LWR (normal reactor)	500 GJ/kg
Natural uranium, in LWR with U & Pu recycle	650 GJ/kg
Natural uranium, in FNR	28,000 GJ/kg
Uranium enriched to 3.5%, in LWR	3900 GJ/kg

Appendix C: Costs of producing hydrogen

While the costs of producing hydrogen range between $2 and $7 per kg globally. The King Abdullah Petroleum Studies and Research Center (KAPSARC) of Saudi Arabia predicted that in the long term, rates of $1 per kg should be reliably attainable in Saudi Arabia, making them easily the cheapest in the world.

Appendix D: PTX technology

What is PtX project?

PtX is the process of converting renewable electricity, from wind and sun, but also from hydro or geo-thermal power plants, into a wide variety (X) of end products. It starts with producing hydrogen in electrolysers using renewable electricity to split water (H2O) into its components hydrogen (H2) and oxygen (O2).

What is a PtX plant?

Power-to-X (PtX) is a next generation renewable energy and storage technology which represents a significant new chapter in large-scale decarbonization of e.g infrastructure and agriculture. The plant will rely on electricity from renewables as sole source of energy.

What is PtX (P2X) hydrogen?

This means that green hydrogen is absolutely essential to a successful energy transition and to achieving international climate goals. It

can be used, among other things, to produce climate-neutral fuels. They are called Power-to-X products (PtX). Green hydrogen can also be used to store energy.

What is PtX technology?

Power-to-X technology, (PtX – power to liquid, power to gas or power to ammonia) holds promise as a renewable, non-biogenic technology to produce fuels. PtX uses CO2, water and renewable electricity to produced synthetic liquid hydrocarbon fuels and chemicals.

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