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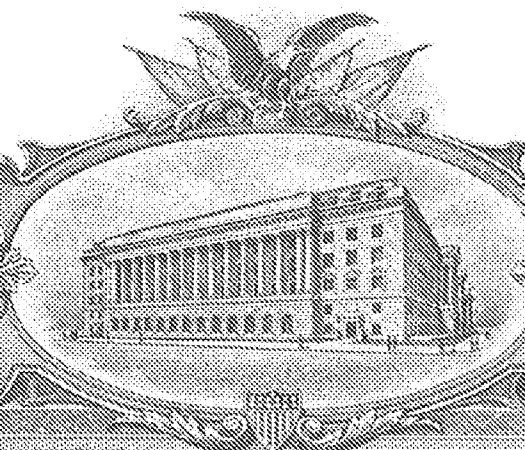
Application number: 63349892

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June 29, 2023

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APPLICATION NUMBER: 63/349,892

FILING DATE: *June 07, 2022*

THE COUNTRY CODE AND NUMBER OF YOUR PRIORITY APPLICATION, TO BE USED FOR FILING ABROAD UNDER THE PARIS CONVENTION, IS *US63/349,892*



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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	P296927.US.01_515365-8
		Application Number	
Title of Invention	INTEGRATION OF NATURAL HYDROGEN RESERVOIR STORAGE CAPACITY OR SUITABLE SUBSURFACE RESERVOIRS WITH OTHER HYDROGEN SOURCES AND SINKS		
The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76. This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.			

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☐	Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)
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Inventor Information:

Inventor	1				Remove	
Legal Name						
Prefix	Given Name	Middle Name	Family Name	Suffix		
	Peter	L.	Johnson			
Residence Information (Select One) • US Residency Non US Residency Active US Military Service						
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Address 2	7251 Sawmill Road, Suite 100					
City	Dublin	State/Province	OH			
Postal Code	43016	Country	US			
All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the Add button.						Add

Correspondence Information:

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☐ An Address is being provided for the correspondence information of this application.			
Customer Number	153511		
Email Address	ip.docket.slc@dorsey.com	Add Email	Remove Email

Application Information:

Title of the Invention	INTEGRATION OF NATURAL HYDROGEN RESERVOIR STORAGE CAPACITY OR SUITABLE SUBSURFACE RESERVOIRS WITH OTHER HYDROGEN SOURCES AND SINKS		
Attorney Docket Number	P296927.US.01_515365-8	Small Entity Status Claimed	☒
Application Type	Provisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	1	Suggested Figure for Publication (if any)	

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	P296927.US.01_515365-8
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Title of Invention	INTEGRATION OF NATURAL HYDROGEN RESERVOIR STORAGE CAPACITY OR SUITABLE SUBSURFACE RESERVOIRS WITH OTHER HYDROGEN SOURCES AND SINKS		

Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not be** the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

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Please Select One:	☒ Customer Number	☐ US Patent Practitioner	☐ Limited Recognition (37 CFR 11.9)
Customer Number	153511		

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.

When referring to the current application, please leave the "Application Number" field blank.

Prior Application Status		Remove	
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	P296927.US.01_515365-8
		Application Number	
Title of Invention	INTEGRATION OF NATURAL HYDROGEN RESERVOIR STORAGE CAPACITY OR SUITABLE SUBSURFACE RESERVOIRS WITH OTHER HYDROGEN SOURCES AND SINKS		

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)ⁱ the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

Application Number	Country ⁱ	Filing Date (YYYY-MM-DD)	Access Code ⁱ (if applicable)

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Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.

NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	P296927.US.01_515365-8
		Application Number	
Title of Invention	INTEGRATION OF NATURAL HYDROGEN RESERVOIR STORAGE CAPACITY OR SUITABLE SUBSURFACE RESERVOIRS WITH OTHER HYDROGEN SOURCES AND SINKS		

Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

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1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

A. Priority Document Exchange (PDX) - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	P296927.US.01_515365-8
		Application Number	
Title of Invention	INTEGRATION OF NATURAL HYDROGEN RESERVOIR STORAGE CAPACITY OR SUITABLE SUBSURFACE RESERVOIRS WITH OTHER HYDROGEN SOURCES AND SINKS		

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Applicant	1	Remove
------------------	----------	------------------------

If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.

[Clear](#)

☒ Assignee	Legal Representative under 35 U.S.C. 117	Joint Inventor
Person to whom the inventor is obligated to assign.	Person who shows sufficient proprietary interest	

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

Name of the Deceased or Legally Incapacitated Inventor:

If the Applicant is an Organization check here. ☒

Organization Name	Koloma, Inc.
-------------------	--------------

Mailing Address Information For Applicant:

Address 1	7251 Sawmill Road, Suite 100		
Address 2			
City	Dublin	State/Province	OH
Country	US	Postal Code	43016
Phone Number		Fax Number	
Email Address			

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	P296927.US.01_515365-8
	Application Number	
Title of Invention	INTEGRATION OF NATURAL HYDROGEN RESERVOIR STORAGE CAPACITY OR SUITABLE SUBSURFACE RESERVOIRS WITH OTHER HYDROGEN SOURCES AND SINKS	

Assignee	1
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Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

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This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

Signature	/Nathan Orme/		Date (YYYY-MM-DD)	2022-06-07
First Name	Nathan	Last Name	Orme	Registration Number
				68918

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	P296927.US.01_515365-8
		Application Number	
Title of Invention	INTEGRATION OF NATURAL HYDROGEN RESERVOIR STORAGE CAPACITY OR SUITABLE SUBSURFACE RESERVOIRS WITH OTHER HYDROGEN SOURCES AND SINKS		

This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
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1/1

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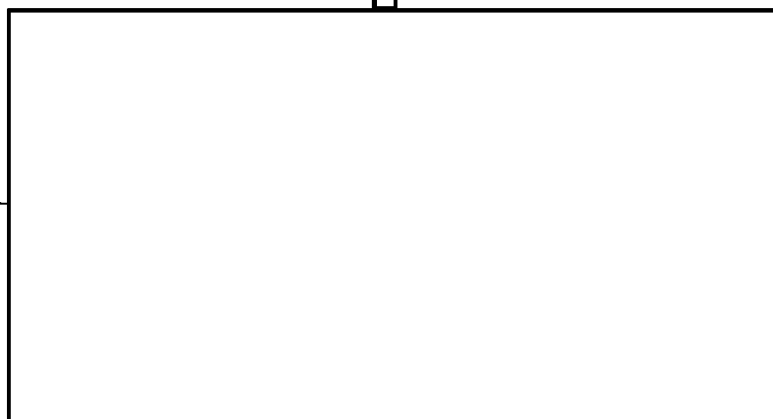


FIG. 1

Electronic Acknowledgement Receipt	
EFS ID:	45896654
Application Number:	63349892
International Application Number:	
Confirmation Number:	4393
Title of Invention:	INTEGRATION OF NATURAL HYDROGEN RESERVOIR STORAGE CAPACITY OR SUITABLE SUBSURFACE RESERVOIRS WITH OTHER HYDROGEN SOURCES AND SINKS
First Named Inventor/Applicant Name:	Peter L. Johnson
Customer Number:	153511
Filer:	Nathan Michael Orme/Eve Stark
Filer Authorized By:	Nathan Michael Orme
Attorney Docket Number:	P296927.US.01_515365-8
Receipt Date:	07-JUN-2022
Filing Date:	
Time Stamp:	18:12:47
Application Type:	Provisional

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	\$ 150
RAM confirmation Number	E202267113494015
Deposit Account	506181
Authorized User	Eve Stark
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: 37 CFR 1.16 (National application filing, search, and examination fees) 37 CFR 1.17 (Patent application and reexamination processing fees)	

37 CFR 1.19 (Document supply fees)
37 CFR 1.20 (Post Issuance fees)
37 CFR 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Application Data Sheet	20220607_P296927US01_5153 65-8_USProv-ADS.pdf	1255893	no	8
			fbfd3c907b75d3abbd4140c206694e461faf0c69		
Warnings:					
Information:					
2	Drawings-only black and white line drawings	20220607_P296927US01_5153 65-8_USProv-Drawings.pdf	45000	no	1
			36b362098a9f4a662b596121fbca817e49e33583		
Warnings:					
Information:					
3	Specification	20220607_P296927US01_5153 65-8_USProv-Specification.pdf	261109	no	22
			fa6e9ecede30a43e8b7cf44809a1346c58ebcb1e		
Warnings:					
Information:					
4	Fee Worksheet (SB06)	fee-info.pdf	37978	no	2
			995a91019cd1d8c6b153397a40100778eeab5a83		
Warnings:					
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Total Files Size (in bytes):			1599980		

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New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

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PROVISIONAL PATENT APPLICATION
Docket No. 515365-00008

UNITED STATES PROVISIONAL PATENT APPLICATION

of

Peter L. Johnson

for

**INTEGRATION OF NATURAL HYDROGEN RESERVOIR STORAGE CAPACITY OR
SUITABLE SUBSURFACE RESERVOIRS WITH OTHER HYDROGEN SOURCES
AND SINKS**

INTEGRATION OF NATURAL HYDROGEN RESERVOIR STORAGE CAPACITY OR SUITABLE SUBSURFACE RESERVOIRS WITH OTHER HYDROGEN SOURCES AND SINKS

TECHNICAL FIELD

[0001] Embodiments of the present disclosure relate generally to the field of geology or geophysics. Some embodiments disclose methods of subsurface exploration for natural resources, including hydrogen and carbon dioxide. More particularly, the present disclosure relates to methods for determining and quantifying the presence of hydrogen and carbon dioxide occurrences and accumulations in the subsurface. Other embodiments disclose methods for monitoring and quantifying the subsurface storage, migration, and recovery of hydrogen and the subsurface storage, migration, recovery, and carbon sequestration by mineralization of carbon dioxide.

[0002] This section is intended to introduce various aspects of the technical field, which may be associated with embodiments described in this disclosure. Thus, the forgoing discussion in this section provides a framework for better understanding the disclosure, and is not to be viewed as an admission of prior art.

SUMMARY

[0003] Embodiments are directed to methods of establishing the ability of a reservoir to hold vast amounts of hydrogen (H₂) at or above hydrostatic pressure, recover it at an economic and efficient rate, connect that reservoir to hydrogen demand sinks via pipeline or other means of transportation, and integrate that reservoir with surface based hydrogen production systems.

[0004] In some embodiments, a method to provide hydrogen can include connecting a hydrogen storage reservoir to a hydrogen production system and injecting hydrogen from the hydrogen production system into the hydrogen storage reservoir. The method can further include extracting the injected hydrogen as required for energy production. In some embodiments, extracting the injected hydrogen occurs after the hydrogen storage reservoir is depleted of natural hydrogen from the hydrogen storage reservoir. In other embodiments, extracting the injected hydrogen occurs in parallel with depletion of natural hydrogen from the hydrogen storage reservoir.

[0005] A hydrogen reservoir can include a porous subsurface rock and an injection well configured to supply hydrogen gas to the porous subsurface rock. In some embodiments, the hydrogen gas is stored at or above hydrostatic pressure. The hydrogen reservoir can further include carbon dioxide within the porous subsurface rock. In some embodiments, the carbon dioxide can be in a super critical state.

[0006] In some embodiments, a method to store carbon dioxide (CO₂) can include connecting a reformer to a natural hydrogen reservoir; the reformer configured to capture CO₂ and injecting captured CO₂ into the natural hydrogen reservoir. The method can further include mineralizing the captured CO₂. The reformer can include at least one of a steam methane reformer or autothermal reformer.

[0007] Features from any of the disclosed embodiments may be used in combination with one another, without limitation. In addition, other features and advantages of the present disclosure will become apparent to those of ordinary skill in the art through consideration of the following detailed description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The drawings illustrate several embodiments of the invention, wherein identical reference numerals refer to identical or similar elements or features in different views or embodiments shown in the drawings.

[0009] FIG. 1 is a block diagram of a system for providing hydrogen, according to an embodiment.

DETAILED DESCRIPTION

[0010] Embodiments disclosed herein methods of establishing the ability of a reservoir to hold vast amounts of hydrogen (H₂) at or above hydrostatic pressure, recover it at an economic and efficient rate, connect that reservoir to hydrogen demand sinks via pipeline or other means of transportation, and integrate that reservoir with surface based hydrogen production systems.

[0011] Although the present specification focusses on hydrogen and carbon dioxide, it is understood that the techniques disclosed herein are not so limited and can find application in the identification and quantitative assessment of other subsurface materials, including other gases,

minerals and gems, as well as, materials found in large structures such as foundations, dams, hydroelectric facilities and nuclear facilities to name a few.

[0012] In the production of natural resources from formations within the earth, a well or borehole is drilled into the earth to the location where the natural resource is believed to be located. Similarly in the sequestration of greenhouse gases in formations within the earth, a well or borehole is drilled into the earth to the location where the greenhouse gas will be injected, located and sequestered. These natural resources may be hydrogen; helium; carbon dioxide; methane or other hydrocarbon gases; a dihydrogen sulfide; a hydrogen reservoir; a helium reservoir; a carbon dioxide reservoir; a reservoir rich in dihydrogen sulfide; a reservoir rich in hydrocarbons; the natural resource may be fresh water; brackish water; brine; it may be a heat source for geothermal energy; or it may be some other natural resource, ore deposit, mineral, metal, or gem that is located within the ground.

[0013] These resource-containing formations may be a few hundred feet, a few thousand feet, or tens of thousands of feet below the surface of the earth, including under the floor of a body of water, e.g., below the sea floor or beneath other natural resources, e.g., below aquifers. In addition to being at various depths within the earth, these formations may cover areas of differing sizes, shapes and volumes.

[0014] Typically, and by way of general illustration, in drilling a well an initial borehole is made into the earth (e.g., the surface of land or seabed) and then subsequent and smaller diameter boreholes are drilled to extend the overall depth of the borehole. In this manner as the overall borehole gets deeper its diameter becomes smaller; resulting in what can be envisioned as a telescoping assembly of holes with the largest diameter hole being at the top of the borehole closest to the surface of the earth.

[0015] Thus, by way of example, the starting phases of a subsea drill process may be explained in general as follows. Once the drilling rig is positioned on the surface of the water over the area where drilling is to take place, an initial borehole is made by drilling a 36" hole in the earth to a depth of about 200 - 300 ft. below the seafloor. A 30" casing is inserted into this initial borehole. This 30" casing may also be called a conductor. The 30" conductor may or may not be cemented into place. During this drilling operation a riser is generally not used and the cuttings from the borehole, e.g., the earth and other material removed from the borehole by the drilling activity are returned to the seafloor. Next, a 26" diameter borehole is drilled within the

30" casing, extending the depth of the borehole to about 1,000 - 1,500 ft. This drilling operation may also be conducted without using a riser. A 20" casing is then inserted into the 30" conductor and 26" borehole. This 20" casing is cemented into place. The 20" casing has a wellhead secured to it. (In other operations an additional smaller diameter borehole may be drilled, and a smaller diameter casing inserted into that borehole with the wellhead being secured to that smaller diameter casing.) A blow out preventer (BOP) is then secured to a riser and lowered by the riser to the sea floor; where the BOP is secured to the wellhead. From this point forward all drilling activity in the borehole takes place through the riser and the BOP.

[0016] It should be noted that riserless subsea drilling operations are also contemplated.

[0017] For a land-based drill process, the steps are similar, although the large diameter tubulars, 30" – 20" are typically not used. Thus, and generally, there is a surface casing that is typically about 13 3/8" diameter. This may extend from the surface (*e.g.*, wellhead and BOP) to depths of tens of feet to hundreds of feet. One of the purposes of the surface casing is to meet environmental concerns in protecting ground water and prevent surface casing ventflow of greenhouse gases or flammable gases. The surface casing should have sufficiently large diameter to allow the drill string, production equipment such as electronic submersible pumps (ESPs) and circulation mud to pass through. Below the casing one or more different diameter intermediate casings may be used. (It is understood that sections of a borehole may not be cased, which sections are referred to as open hole.) These can have diameters in the range of about 9" to about 7," although larger and smaller sizes may be used, and can extend to depths of thousands and tens of thousands of feet. Inside of the casing and extending from a pay zone, or production zone of the borehole up to and through the wellhead on the surface is the production tubing. There may be a single production tubing or multiple production tubings in a single borehole, with each of the production tubing endings being at different depths.

[0018] Fluid communication between the formation and the well can be greatly increased by the use of hydraulic fracturing techniques. The first uses of hydraulic fracturing date back to the late 1940s and early 1950s. In general, hydraulic fracturing treatments involve forcing fluids down the well and into the formation, where the fluids enter the formation and crack, *e.g.*, force the layers of rock to break apart or fracture. These fractures create channels or flow paths that may have cross sections of a few microns, to a few millimeters, to several millimeters in size, and potentially larger. The fractures may also extend out from the well in all directions for a few

feet, several feet, and tens of feet or further. The fractures may be kept open by using a proppant (e.g., various sized sand grains) that are forced down the well with the fracturing fluid in a single operation. It should be remembered that the longitudinal axis of the well in the reservoir may not be vertical: it may be on an angle (either sloping up or down) or it may be horizontal. The section of the well located within the reservoir, i.e., the section of the formation containing the natural resources, can be called the pay zone.

[0019] As used herein, unless specified otherwise, the terms “hydrogen exploration and production,” “carbon dioxide exploration and production,” “helium exploration and production,” “dihydrogen sulfide exploration and production,” “exploration and production activities,” “E&P,” and “E&P activities,” and similar such terms are to be given their broadest possible meaning, and include surveying, geological analysis, well planning, reservoir planning, reservoir management, drilling a well, workover and completion activities, hydrogen production, flowing of hydrogen from a well, collection of hydrogen, secondary and tertiary recovery from a well, the management of flowing hydrogen from a well, and any other upstream activities.

[0020] As used herein, unless specified otherwise, the term “earth” should be given its broadest possible meaning, and includes, the ground, all natural materials, such as rocks, and artificial materials, such as concrete, that are or may be found in the ground.

[0021] As used herein, unless specified otherwise "offshore" and "offshore drilling activities" and similar such terms are used in their broadest sense and would include drilling activities on, or in, any body of water, whether fresh or salt water, whether manmade or naturally occurring, such as for example rivers, lakes, canals, inland seas, oceans, seas, such as the North Sea, bays and gulfs, such as the Gulf of Mexico. As used herein, unless specified otherwise the term "offshore drilling rig" is to be given its broadest possible meaning and would include fixed towers, tenders, platforms, barges, jack-ups, floating platforms, drill ships, dynamically positioned drill ships, semi-submersibles and dynamically positioned semi-submersibles. As used herein, unless specified otherwise the term "seafloor" is to be given its broadest possible meaning and would include any surface of the earth that lies under, or is at the bottom of, any body of water, whether fresh or salt water, whether manmade or naturally occurring.

[0022] As used herein, unless specified otherwise, the term “borehole” should be given its broadest possible meaning and includes any opening that is created in the earth that is substantially longer than it is wide, such as a well, a well bore, a well hole, a micro hole, a

slimhole and other terms commonly used or known in the arts to define these types of narrow long passages. Wells would further include exploratory, discovery, production, abandoned, reentered, reworked, recirculation, and injection wells. They would include both cased and uncased wells, and sections of those wells. Uncased wells, or section of wells, also are called open holes, boreholes, open boreholes, open bores, or open hole sections. Boreholes may further have segments or sections that have different orientations, they may have straight sections and arcuate sections and combinations thereof. Thus, as used herein unless expressly provided otherwise, the "bottom" of a borehole, the "bottom surface" of the borehole and similar terms refer to the end of the borehole, *i.e.*, that portion of the borehole furthest along the path of the borehole from the borehole's opening, the surface of the earth, or the borehole's beginning. The terms "side" and "wall" of a borehole should be given their broadest possible meaning and include the longitudinal surfaces of the borehole, whether or not casing or a liner is present, as such, these terms would include the sides of an open borehole or the sides of the casing that has been positioned within a borehole. Boreholes may be made up of a single passage, multiple passages, connected passages, (e.g., branched configuration, fishboned configuration, duallateral configuration, trilateral configuration, quadrilateral configuration, pitchfork configuration, pinnate configuration, or comb configuration), and combinations and variations thereof.

[0023] Boreholes are generally formed and advanced by using mechanical drilling equipment having a rotating drilling tool (e.g., a bit). For example, and in general, when creating a borehole in the earth, a drilling bit extends to and into the earth and rotated to create a hole in the earth. To perform the drilling operation the bit must be forced against the material to be removed with a sufficient force to exceed the shear strength, compressive strength or combinations thereof, of that material. The material that is cut from the earth is generally known as cuttings or drill cuttings (e.g., waste), which may be chips of rock, dust, rock fibers and other types of materials and structures that may be created by the bit's interactions with the earth. These cuttings are typically removed from the borehole by the use of fluids, which fluids can be liquids, foams or gases, or other materials known to the art.

[0024] As used herein, unless specified otherwise, the term "drill pipe" is to be given its broadest possible meaning and includes all forms of pipe used for drilling activities; and refers to a single section or piece of pipe. As used herein the terms "stand of drill pipe," "drill pipe stand," "stand of pipe," "stand" and similar type terms should be given their broadest possible meaning

and include two, three or four sections of drill pipe that have been connected (*e.g.*, joined together) typically by joints having threaded connections. As used herein the terms "drill string," "string," "string of drill pipe," "string of pipe" and similar type terms should be given their broadest definition and would include a stand or stands joined together for the purpose of being employed in a borehole. Thus, a drill string could include many stands and many hundreds of sections of drill pipe.

[0025] As used herein, unless specified otherwise, the terms "formation," "reservoir," "pay zone," and similar terms, are to be given their broadest possible meanings and would include all locations, areas, and geological features within the earth that contain, may contain, or are believed to contain, hydrogen, carbon dioxide, helium, dihydrogen sulfide.

[0026] As used herein, unless specified otherwise, the terms "field," "oil field," "gas field" and similar terms, are to be given their broadest possible meanings, and would include any area of land, sea floor, or water that is loosely or directly associated with a geologic formation, and more particularly with a resource containing formation, thus, a field may have one or more exploratory and producing wells associated with it, a field may have one or more governmental body or private resource leases associated with it, and one or more field(s) may be directly associated with a resource containing formation.

[0027] As used herein, unless specified otherwise, the terms "conventional hydrogen," "conventional carbon dioxide," "conventional helium," "conventional dihydrogen sulfide," "conventional natural gas," "conventional," "conventional production" and similar such terms are to be given their broadest possible meaning and include hydrogen, carbon dioxide, helium, or dihydrogen sulfide that are trapped in structures or other trapping mechanisms in the earth. Generally, in these conventional formations the hydrogen, carbon dioxide, helium, dihydrogen sulfide, or natural gas have migrated in permeable, or semi-permeable formations to a trap, or area where they are accumulated. Typically, in conventional formations a non-porous, relatively impermeable layer is above, or encompassing the area of accumulated hydrogen, carbon dioxide, helium, dihydrogen sulfide, or natural gas in essence trapping the hydrogen, carbon dioxide, helium, dihydrogen sulfide, or natural gas in the accumulation. Conventional reservoirs have been historically the sources of the vast majority of hydrogen, carbon dioxide, helium, and dihydrogen sulfide observed. As used herein, unless specified otherwise, the terms "unconventional hydrogen," "unconventional carbon dioxide," "unconventional helium,"

“unconventional dihydrogen sulfide,” “unconventional natural gas,” “unconventional,” “unconventional production” and similar such terms are to be given their broadest possible meaning and includes hydrogen, carbon dioxide, helium, dihydrogen sulfide, or natural gas that are held in impermeable rock, and which have not migrated to traps or areas of accumulation.

[0028] As used herein unless specified otherwise, the recitation of ranges of values herein is merely intended to serve as a shorthand method of referring individually to each separate value falling within the range. Unless otherwise indicated herein, each individual value within a range is incorporated into the specification as if it were individually recited herein.

[0029] Generally, the term “about” as used herein unless stated otherwise is meant to encompass a variance or range of $\pm 10\%$, the experimental or instrument error associated with obtaining the stated value, and preferably the larger of these.

[0030] As used herein, unless stated otherwise, room temperature is 25°C. And, standard temperature and pressure is 25°C and 1 atmosphere.

[0031] The term “CO₂e” is used to define carbon dioxide equivalence of other, more potent greenhouse gases, to carbon dioxide (i.e., methane and nitrous oxide) on a global warming potential basis of 100 years, based on IPCC AR5 methodology. The term “carbon intensity” is taken to mean the lifecycle CO₂e generated per unit mass of a product.

[0032] CO₂ is widely recognized as a greenhouse gas (GHG), and the continued accumulation of CO₂ and other GHGs in the atmosphere are expected to cause problematic changes to global ecosystems and contribute to myriad other problems, such as ocean acidification and sea level rise. The two primary causes of carbon emissions globally are the use of fossil fuels for power generation and transportation.

[0033] Given the risks of CO₂ emissions, significant work has gone into finding replacements to existing high carbon energy sources, or ways to decarbonize existing energy sources. However, many of these low carbon alternatives have been uneconomic or not dispatchable enough to replace the current options.

[0034] In power generation, the alternatives to the highly reliable, low cost, but high emission sources (gas and coal) are either dispatchable and expensive (e.g., nuclear, hydroelectric, green hydrogen, or blue hydrogen), or inexpensive and intermittent (e.g., solar and wind, green hydrogen in some cases). There is only one existing source that is both lower cost and dispatchable, and that is geothermal. However, geothermal resources are limited, many of

the economically productive geothermal resources have already been developed and are nearing end of life, and many geothermal resources are already in decline. As such, the growth outlook for geothermal is limited without significant technical advances.

[0035] Green hydrogen (hydrogen produced from water without the utilization of fossil fuels), which is generated by electrolysis powered from either solar, wind, hydroelectric, or geothermal energy can be a reliable source of low carbon energy when coupled with storage, but high capital cost, intermittent production due to intermittent energy sources or high cost of energy when grid connected, and the high cost and low availability of suitable hydrogen storage resources limits applicability. In addition, electrolysis consumes significantly more energy to produce the hydrogen than what is stored in the hydrogen, resulting in a low round trip efficiency in the system.

[0036] Blue hydrogen faces a similar set of problems to green hydrogen: it takes a low cost, high emission fuel source like coal or natural gas, and by adding expensive and parasitic carbon capture facilities, converts this low-cost-high-emission source of energy into a high-cost-low-emission source. Thus, even though large volumes of hydrogen can be formed in processes that subsequently prevent greenhouse gas emissions from reaching the atmosphere, the newly developed hydrogen resource is not cost competitive with other forms of energy derived from fossil fuels. Additionally, the challenges around finding carbon sequestration resources that can be used to permanently store the captured carbon from these processes result in limited opportunities to deploy these technologies today.

[0037] Natural hydrogen (or “gold hydrogen”), produced from the subsurface by drilling and producing wells can provide an abundant source of low emission, low cost, fully dispatchable energy.

[0038] Each of these energy sources and their inherent advantages and limitations are also relevant to transportation. When considering transportation fuels, by far the major sources of fuel are diesel and gasoline, both derived from crude oil production. Additionally, in recent years, electric vehicles have been gaining market share, but the cost for electric vehicles is still more expensive than fossil fueled equivalents and limitations exist regarding cost, recharge time, and primary resources for battery and energy storage. Given the weight of batteries, electric long-haul trucking is also challenged, and most long-haul truck manufacturers are in search of affordable, low carbon options such as hydrogen-fueled trucking.

[0039] Natural hydrogen can be an answer to the low carbon, low cost, reliable transportation problem for long-haul trucking and potentially other forms of transportation. As for other types of transportation, natural hydrogen as a compressed or liquified product, or as a feedstock for synthetic liquid fuel (“efuels”), would be a reliable low cost, low carbon solution. Additionally, natural hydrogen could be combined with nitrogen to produce a carbon free ammonia product, which is being widely discussed as a potential replacement for bunker fuel for shipping.

[0040] Direct Emissions Reduction: Because there are no direct CO₂ emissions from the combustion or typical use of hydrogen, the reduction in CO₂ emissions is a function of what the hydrogen is replacing. In most cases, hydrogen is a substitute for natural gas, either in ammonia production, refining, as a feedstock for other chemicals, or in power generation.

[0041] In the case of ammonia production and refining, natural gas is used to produce hydrogen via steam methane reformation reactions, which is used as a chemical feedstock in both the refining process and the ammonia production process. Today, more than 95% of hydrogen is produced using natural gas in steam methane reformers (SMRs). The carbon intensity of hydrogen production using SMRs without carbon capture is 10.4 tonnes of CO₂ emitted for each tonne of hydrogen produced. As such, direct replacement of natural hydrogen for hydrogen manufactured by SMR processes results in a CO₂ reduction of 10.4 tonnes CO₂/tonne H₂.

[0042] In power generation with gas turbines, hydrogen must displace the energy (btu) equivalent of natural gas. The energy density of hydrogen is 290 btu/cf or 51,682 btu/lb. By comparison, the energy density of natural gas is 983 btu/cf or 20,267 btu/lb, while the carbon intensity of natural gas is 52.91 kg CO₂/mmbtu CH₄ or 54.87 kg CO₂/mcf CH₄, or 3.5 kg CO₂/kg CH₄.

[0043] Because hydrogen is 2.6 times more energy dense per unit mass than natural gas, only 40% of the gross tonnage of fuel is required to achieve the same energy output. As such, burning one tonne of H₂ for power generation reduces natural gas consumption by about 2.6 tonnes, and thus CO₂ emissions by 9.1 tonnes.

[0044] Comparing natural hydrogen to hydrogen produced by electrolysis, the carbon reduction is a function of the carbon intensity of the power used in the electrolysis process. However, although there may be large indirect emissions associated with electrolysis, there are

no direct emissions. Thus, natural hydrogen does not result in a direct emissions reduction as compared to electrolytically produced hydrogen.

[0045] Indirect Emissions Reduction: An analysis of the lifecycle carbon intensity of natural hydrogen using OPGEE has shown the lifecycle carbon intensity of natural hydrogen to be in the range of 0.1 to 0.4 tonnes CO₂/tonne H₂. Similar studies are not available for other methods of hydrogen production. However, using an average grid intensity of 0.5 tonnes CO₂/MWh, and given that electrolysis requires approximately 50 MWh/tonne H₂ produced, the indirect emissions associated with electrolysis are about 25 tonnes CO₂/tonne H₂ produced assuming grid power. Of course, electrolysis unit operators can purchase Renewable Energy Credits to synthetically reduce the carbon footprint of their power usage, but market recognition of this as a method for eliminating real time carbon emissions may not be permanent.

[0046] The realization of abundant natural hydrogen can achieve significant reductions in equivalent carbon emissions. As indicated below in Figures 1 and 2, an energy system that includes hydrogen can provide relatively low emissions and low costs coupled with a high reliability energy source. The benefits are included in both power generation and the transportation costs. In some embodiments, the hydrogen can be a natural source, either from a geothermal reservoir or other natural or synthetic hydrogen source.

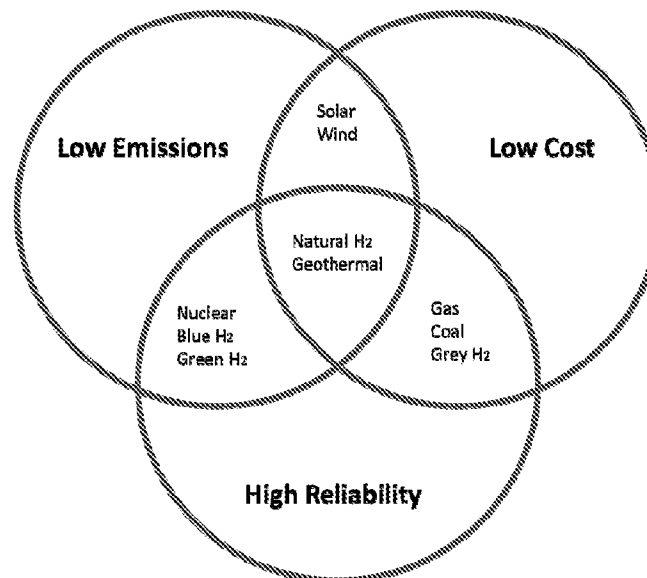


Figure 1: Power source Cost, Emissions, and Reliability

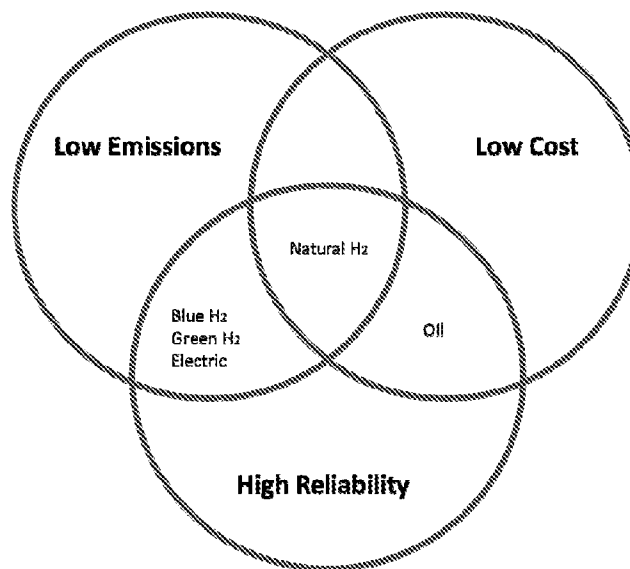


Figure 2: Transportation fuel Cost, Emissions, and Reliability

[0047] There are efforts to explore and develop new salt cavern capacity for underground hydrogen storage. Salt, because of its close packing structure and low porosity, along with self-healing following deformation events, can hold nearly all gases at high pressure. However, salt caverns are relatively small on average. For example, most salt caverns are sized to be able to store approximately 6,000-10,000 metric tons of hydrogen. If used at peak storage capacity, where 80% of the gas in the cavern is exhausted and refilled every day, a 6,000 metric ton cavern could only support approximately 1.75 million metric tons per year of intermittent production. Above ground storage for hydrogen or liquification and storage comes at a very high price that makes them unfeasible for most commercial applications.

[0048] Underground hydrogen storage is thought to be critical to create redundancy in a developing hydrogen economy but also serves the purpose of compensating for the potential irregularity of hydrogen production via renewable energy-driven electrolysis, where the hydrogen production profile might follow wind, solar, or even hydroelectric production profiles in order to achieve the lowest cost of production. Electrolyzed hydrogen producers are generally faced with a challenge: build near the point of production with lowest cost renewables (e.g., desert locations in the southwestern United States for solar, high wind locations like the Great Plains or west Texas for wind, or the Pacific Northwest United States for hydroelectric power) and produce intermittent hydrogen that is not located proximal to a demand sink, or locate electrolyzers near or “over the fence” from a demand sink (offtaker) and pay significant grid

charges, wire charges, and RECs to achieve a flatter production profile near the user. Producers could also build on site buffer storage, but this is widely viewed to be cost prohibitive. “Green” hydrogen producers are stuck between option 1 (low cost, intermittent, and far from and unconnected to demand) and option 2 (high cost, grid connected with synthetic base load, and over the fence).

[0049] Another form of clean hydrogen is natural gas-derived hydrogen from steam methane reforming or autothermal reforming with carbon capture and sequestration on the back end. This also provides geographic and supply chain challenges to a production company, in that locating a “Blue” hydrogen production facility near a demand sink might locate it far away from a geologic CO₂ sink and create transportation challenges for the CO₂, whereas location near a CO₂ storage reservoir may place hydrogen far from the demand sink/offtake. A particularly desirable location for a greenfield blue hydrogen facility would either be on top of a CO₂ sequestration resource with hydrogen production that is connected via pipelines to demand sinks, or over the fence from a H₂ demand sink and pipeline connected to a CO₂ sequestration resource. There are not many options that satisfy both of these conditions.

[0050] Natural hydrogen reservoirs (or other suitable subsurface reservoirs), if they are initially developed because a large supply of naturally trapped hydrogen was discovered, can include a pressure-bearing and sealing capability proven via hundreds of thousands and millions of years of geologic demonstration. The natural hydrogen present in the reservoir can be coupled to a pipeline system where it can be delivered to downstream customers. Generally, the storage capacity in the natural hydrogen reservoirs (or other suitable subsurface reservoirs) can be approximately 1 million metric tons or more. When discharged, it could enable more than one billion metric tons per year of intermittent production. Natural hydrogen reservoirs (or other suitable subsurface reservoirs) tied to electrolyzers can supply H₂ and operate continuously when connected to demand sinks because of the storage capacity.

[0051] Methods of providing H₂ can include connecting a (natural) hydrogen storage reservoir to a hydrogen production system. In some embodiments, the connection can include a pipeline system configured to accommodate hydrogen gas pressures and other related properties. The connection method can include any suitable means of hydrogen transportation to bring H₂ from the natural storage reservoir to the H₂ production system. In some embodiments, the H₂ production system can include electrolysis (e.g., by wind, solar, hydropower, or others) or

reforming, but other production systems may be included. The pipeline can be connected to injection and/or production wells at the H₂ storage reservoir. The reservoir can be configured to hold vast amounts of H₂.

[0052] By connecting renewable powered electrolyzers to a large, geologically proven natural hydrogen reservoir (or other suitable subsurface reservoirs), the electrolysis plant owner is able to overcome their major supply challenges of intermittency and paying high cost for grid connected power to be near the demand sinks. Because the scale of electrolyzers is typically smaller compared to other production methods, ordinarily it would be challenging economically to connect them via pipeline to demand sinks, but by pairing them with large natural hydrogen reservoirs (or other suitable subsurface reservoirs), connectivity of the system would be much easier to justify economically.

[0053] Providing hydrogen can further include injecting H₂ from the hydrogen production system into the H₂ storage reservoir (e.g., new or depleted natural hydrogen reservoir) and then extracting the injected H₂ as required for energy production. In some embodiments, the stability and redundancy of a new or depleted natural hydrogen reservoir (or other suitable subsurface reservoirs), proven as a resource that can store H₂ at high pressures, would also allow for long term top side hydrogen conversion infrastructure, like an ammonia plant, synthetic fuels plant, or the like, to be built with an anticipated lifetime much longer than the hydrogen supply in the reservoir itself as it can be repurposed as a storage resource for other means of H₂ production. In some embodiments, when the conversion infrastructure includes electrolyzers, the oxygen from the electrolyzer could be used as a feedstock for autothermal reformers or as an oxidant for any fired processes like power production, compressors, pumps, or other equipment. Heat from the electrolyzer could also be used to augment steam production in a power plant or steam production for downhole injection. A natural hydrogen reservoir (or other suitable subsurface reservoirs) may be utilized a hydrogen hub and the center of a hydrogen ecosystem that will allow for full use of all byproducts from the electrolysis process or other hydrogen production processes.

[0054] In some embodiments, extracting the injected H₂ occurs after the hydrogen storage reservoir is depleted of natural hydrogen from the hydrogen storage reservoir. In other embodiments, extracting the injected H₂ occurs in parallel with depletion of natural H₂ from the hydrogen storage reservoir.

[0055] In some embodiments, a hydrogen reservoir can include a porous subsurface rock and an injection well configured to supply H₂ gas to the porous subsurface rock. In some embodiments, the H₂ gas is stored at or above hydrostatic pressure.

[0056] In some embodiments, the hydrogen reservoir can include carbon dioxide (CO₂) within the porous subsurface rock. The CO₂ can be super critical. CO₂ can be utilized to create pressure support and reduce viscosity of oil reservoirs, in a technique known as Enhanced Oil Recovery, or EOR. For “Blue hydrogen” prospective producers, CO₂ storage resources, be it a saline aquifer, a depleted oil or gas reservoir, or an EOR resource, is generally not connected via CO₂ pipeline to a hydrogen demand sink. This is resolved by building sufficient top side infrastructure that hydrogen can be converted into more easily transportable liquid products like ammonia or synthetic fuel top side above a CO₂ storage resource with natural gas connectivity. In some embodiments, large pipeline networks carrying either H₂ or CO₂ may be less necessary. However, a proven natural hydrogen reservoir (or other suitable subsurface reservoirs) can address the challenge.

[0057] The pore space in a natural hydrogen reservoir (or other suitable subsurface reservoirs) can be used to store CO₂, such as from a “Blue” hydrogen production facility built adjacent to or on top of the natural hydrogen reservoir (or other suitable subsurface reservoirs). The CO₂ can be used to provide pressure support to increase recovery of the natural hydrogen in the reservoir and the depleted reservoir could serve as a storage resource for the CO₂. Because the natural hydrogen reservoir can include a pipeline connected to demand sinks (*e.g.*, an injection and/or production well), the challenge of connecting CO₂ storage resources and hydrogen demand is resolved. As hydrogen is removed from a natural hydrogen reservoir, pore space can be freed to store injected CO₂. When the CO₂ is injected to the right depth, the CO₂ would be super critical and would be considerably denser than any remaining H₂ which is present at the top of a dome or trap within the hydrogen reservoir. The freed-up pore space volume, the geologically demonstrated sealing and closure capability of the natural hydrogen reservoir system (or other suitable subsurface reservoir systems) and the use of the CO₂ to provide pressure support to the H₂ provides a method to store CO₂ that can be beneficial.

[0058] In some embodiments, storing CO₂ can include connecting a reformer to a natural hydrogen reservoir. The reformer can be configured to capture CO₂. In some embodiments, the reformer can include at least one of a steam methane reformer, autothermal reformer, or the like.

The reformer can be connected via a pipeline shared with the natural hydrogen reservoir (or other suitable subsurface reservoirs) to downstream hydrogen demand and also configured to capture CO₂ from the process. Storing CO₂ can also include injecting captured CO₂ into the natural hydrogen reservoir. In some embodiments, the CO₂ can be injected via an injection well where it is stored in vacant pore space and may provide pressure support to further hydrogen recovery. In some embodiments, the captured CO₂ can also be injected into underlying source rock where it can be mineralized. Most natural hydrogen reservoirs are above or near source rock that could serve as CO₂ sink through CO₂ mineralization. Such mineralization further increases the CO₂ storage capacity in the natural hydrogen reservoir that may be connected via pipeline to H₂ demand sinks. In some cases, one injection well bore could be used to deliver CO₂ to depleted pore space and also to source rock volume where it could be stored via both sequestration and mineralization.

[0059] In some embodiments, methane separated from the natural hydrogen gas may be utilized as part or all of the feedstock for at least one of a SMR or an autothermal reformer (ATR) system. Oxygen and heat from electrolyzers tied into the same hydrogen storage reservoir (or other suitable subsurface reservoirs) may be utilized to enhance the economics (e.g., the efficiency) of the SMR or ATR system.

[0060] In some embodiments, a system for storing hydrogen may be utilized to perform the methods disclosed herein. FIG. 1 is a block diagram of a system 100 for providing hydrogen, according to an embodiment. The system 100 includes a hydrogen storage reservoir 102, a hydrogen production system 104, and one or more conduits 106 connecting the hydrogen storage reservoir 102 to the hydrogen production system 104. The hydrogen storage reservoir 102 may include a subsurface hydrogen reservoir, such as a natural hydrogen reservoir (e.g., a subsurface reservoir containing natural hydrogen). In some embodiments the hydrogen storage reservoir 102 may include a carbon dioxide or other subsurface gas reservoir that is able to retain hydrogen without leaking hydrogen therefrom. The hydrogen storage reservoir may not be a salt cave. The hydrogen storage reservoir 102 may contain more gases than hydrogen alone, such as carbon dioxide, natural gas, oxygen, nitrogen, any other gas, or combinations of any of the foregoing. The hydrogen production system 104 may include one or more of a reformer system (e.g., SMR, ATR, or the like), an electrolysis system, a pyrolysis system, a plasma reformer, or any other suitable hydrogen production system. The hydrogen production system 104 may include

multiple hydrogen production systems. The one or more conduits 106 may include one or more of wells, pipelines, pipes, or the like. The one or more conduits 106 may include an injection well for injecting one or more gases (e.g., hydrogen) into the hydrogen storage reservoir 102 and a production well for extracting the one or more gases from the hydrogen storage reservoir 102. The system 100 may include one or more pumps to inject hydrogen or any other gas into the hydrogen storage reservoir 102. The one or more pumps may be connected to the one or more conduits 106. The hydrogen storage system 100 may be connected to one or more hydrogen demand sink. The system 100 may be utilized to perform one or more portions of any of the methods disclosed herein.

[0061] It is noted that there is no requirement to provide or address the theory underlying the novel and groundbreaking production rates, performance or other beneficial features and properties that are the subject of, or associated with, embodiments of the present inventions. Nevertheless, various theories are provided in this specification to further advance the art in this important area, and in particular in the important area of hydrogen, dihydrogen sulfide, carbon dioxide, and helium exploration, production and downstream conversion or utilization. These theories put forth in this specification, and unless expressly stated otherwise, in no way limit, restrict or narrow the scope of protection to be afforded the claimed inventions. These theories many not be required or practiced to utilize the present inventions. It is further understood that the present inventions may lead to new, and heretofore unknown theories to explain the conductivities, fractures, drainages, resource production, chemistries, and function-features of embodiments of the methods, articles, materials, devices and system of the present inventions; and such later developed theories shall not limit the scope of protection afforded the present inventions.

[0062] The invention may be embodied in other forms than those specifically disclosed herein without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The various aspects and embodiments disclosed herein are for purposes of illustration and are not intended to be limiting. The various embodiments of devices, systems, activities, methods and operations set forth in this specification may be used with, in or by, various processes, industries and operations, in addition to those embodiments of the Figures and disclosed in this specification. The various embodiments of devices, systems, methods, activities, and operations set forth in this

specification may be used with: other processes industries and operations that may be developed in the future; with existing processes industries and operations, which may be modified, in-part, based on the teachings of this specification; and with other types of gas recovery and valorization systems and methods. Further, the various embodiments of devices, systems, activities, methods, and operations set forth in this specification may be used with each other in different and various combinations. Thus, for example, the configurations provided in the various embodiments of this specification may be used with each other. For example, the components of an embodiment having A, A' and B and the components of an embodiment having A'', C and D can be used with each other in various combination, e.g., A, C, D, and A. A'' C and D, etc., in accordance with the teaching of this specification. Thus, the scope of protection afforded the present inventions should not be limited to a particular embodiment, configuration or arrangement that is set forth in a particular embodiment, example, or in an embodiment in a particular Figure.

[0063] Terms of degree (*e.g.*, “about,” “substantially,” “generally,” etc.) indicate structurally or functionally insignificant variations. In an example, when the term of degree is included with a term indicating quantity, the term of degree is interpreted to mean $\pm 10\%$, $\pm 5\%$, or $+2\%$ of the term indicating quantity. In an example, when the term of degree is used to modify a shape, the term of degree indicates that the shape being modified by the term of degree has the appearance of the disclosed shape. For instance, the term of degree may be used to indicate that the shape may have rounded corners instead of sharp corners, curved edges instead of straight edges, one or more protrusions extending therefrom, is oblong, is the same as the disclosed shape, etc.

CLAIMS

What is claimed is:

1. A method to provide hydrogen, comprising:
connecting a hydrogen storage reservoir to a hydrogen production system;
injecting hydrogen from the hydrogen production system into the hydrogen storage reservoir; and
extracting the injected hydrogen as required for energy production.
2. The method of claim 1, wherein extracting the injected hydrogen occurs after the hydrogen storage reservoir is depleted of natural hydrogen from the hydrogen storage reservoir.
3. The method of claim 1, wherein extracting the injected hydrogen occurs in parallel with depletion of natural hydrogen from the hydrogen storage reservoir.
4. The method of claim 1, wherein the hydrogen storage reservoir is a subsurface geological formation that is depleted of natural hydrogen.
5. A hydrogen reservoir, comprising:
a porous subsurface rock; and
an injection well configured to supply one or more of hydrogen gas or carbon dioxide gas to the porous subsurface rock, wherein the hydrogen gas is stored at or above hydrostatic pressure.
6. The hydrogen reservoir of claim 5, further comprising carbon dioxide within the porous subsurface rock, wherein the carbon dioxide is super critical.
7. The hydrogen reservoir of claim 5, further comprising a production well configured to remove the one or more of hydrogen gas or carbon dioxide gas from the porous subsurface rock.
8. A method to store carbon dioxide (CO₂), comprising:
connecting a reformer to a natural hydrogen reservoir, the reformer configured to capture CO₂;
injecting captured CO₂ into the natural hydrogen reservoir; and
mineralizing the captured CO₂.
9. The method of claim 8, wherein the reformer comprises at least one of a steam methane reformer or an autothermal reformer.
10. A method to provide hydrogen, comprising:

injecting hydrogen from a hydrogen production system into a hydrogen storage reservoir including a subsurface geological formation that has been depleted of natural hydrogen; and

extracting the injected hydrogen as required for energy production.

11. Any of the methods disclosed herein.

12. A system to provide hydrogen, the system comprising:
a natural hydrogen storage reservoir,
a hydrogen production system, and
one or more conduits connecting the natural hydrogen storage reservoir to the hydrogen production system.

13. The system of claim 12, wherein the natural hydrogen storage reservoir includes a natural subsurface hydrogen reservoir.

14. The system of claim 12, wherein the hydrogen production system includes one or more of a reformer system, an electrolysis system, a pyrolysis system, or a plasma reformer.

15. Any of the systems disclosed herein.

ABSTRACT

Embodiments are directed to storing, providing, and using hydrogen with natural hydrogen reservoirs. A hydrogen storage reservoir can be connected to a hydrogen production system and hydrogen from the hydrogen production system can be injected into the hydrogen storage reservoir. The injected hydrogen can be extracted as needed for energy production.