

FLOW DENSITY FLUID DISPLACEMENT TO STORE OR GENERATE POWER**CROSS REFERENCE TO RELATED APPLICATIONS**

[0001] The instant application claims priority to U.S. Application No. 17/214,100 filed on March 26, 2021 which is a continuation-in-part application of U.S. Application No. 16/932,429 filed July 17, 2021. The application also claims priority to U.S. application No. 63/117,355 filed November 23, 2020; U.S. application No. 63/132,778 filed December 31, 2020 and U.S. application No. 63/139,157 filed January 19, 2021. All of the aforementioned applications are hereby incorporated by reference in their entirety.

BACKGROUND OF INVENTION

[0002] Solar, wind, and other intermittent energy sources are becoming increasingly larger proportions of global electricity generation capacity. Due to the intermittency of solar and wind energy, electricity grids and other infrastructure which may soon rely on large proportions of wind and solar power generation will require electricity storage to match electricity supply with electricity demand. The amount of electricity storage capacity required generally increases with increasing penetration of intermittent renewable energy sources, especially in solar dominant, or wind dominant electricity grids, and electricity grids with limited geographic distribution. The required duration of the electricity storage capacity also generally increases with increasing intermittent renewable energy penetration. For example, in an electricity grid with a large proportion of solar photovoltaic power, power generation may be insufficient at night, and thus, 10 – 16 hour duration electricity storage may be required to support nighttime grid electricity needs. 80% solar and wind energy penetration may be feasible in the United States with 12 hour duration electricity storage. Notably, 100% solar and wind energy penetration is only feasible with at least 3 weeks of electricity storage duration due to the tendency for wind and / or solar to produce at less than predicted rates at least once a year and / or due to seasonal changes in the solar and / or wind energy. Prior art energy storage technologies are too expensive and / or geographically limited to satisfy the multiple terawatt hours of long duration electricity storage required for a high penetration of solar and wind power generation globally.

[0003] Electricity storage technologies are compared on various factors. Levelized cost, or levelized cost of electricity (LCOE) or levelized cost of storage (LCOS) is generally considered the primary or most important factor. Energy storage customers, such as project developers, electric power utilities, and other customers, generally employ levelized cost as their primary metric for comparing electricity storage technologies, wherein the lower levelized cost, the more

economically desirable the electricity storage technology is relative to other options. Levelized cost calculations may include values of including, but are not limited to, one or more or a combination of the following variables: capital cost, or cost of capital, or discount rate, or capacity utilization, or round-trip energy efficiency, or cost of land, or rate of power capacity degradation, or rate of energy storage capacity degradation, or balance of plant, or land use, or geographic limitation, or end-of-life costs, or cost per MW power capacity, or cost per MWh electricity storage capacity. Prior art electricity storage technologies generally have high levelized cost due deficiencies in one or more or a combination of the previous described variables. For example, lithium ion batteries have a high capital cost, significant power capacity degradation, significant energy capacity degradation, land use, and high end-of-life costs. For example, compressed air energy storage has low round trip energy efficiency and geographic limitations. For example, pumped hydro has high land use and geographic limitations. For example, hydrogen electricity storage has low round trip energy efficiency, high cost per MW power capacity, and high rate of power capacity degradation.

[0004] Other factors may include, but are not limited to, one or more or a combination of the following: environmental impact of manufacturing, environmental impact of land use, material constraints, end-of-life disposal, recyclability, labor use, local labor content, local economic impact, and required maintenance.

- For example, lithium ion batteries suffer from the following deficiencies relating to the above factors:
 - Negative environmental impact of manufacturing, including the manufacturing of the material inputs
 - Material constraints of lithium, cobalt, nickel, and graphite
 - Short lifespan and end of life disposal challenges.
 - Lithium ion batteries are currently not recyclable
 - Local labor content is generally minimal, especially for the high cost material inputs, including lithium, nickel, and cobalt

- Unethical labor practices and downstream environmental impacts, especially in the mining and refining of the required metals and materials, including cobalt and graphite
- The local job creation and related economic impact is minimal because the most of the cost and labor occurs in large manufacturing and mining operations generally located far from the renewable energy project or energy storage project site.
- Required maintenance is high because of the need for thermal regulation, balance of plant, and augmentation. Augmentation is the installation of additional new lithium ion batteries to makeup for the loss in energy storage and / or power capacity which naturally occurs over time in lithium ion battery energy storage facilities. In large scale lithium ion battery energy storage sites, significant ‘augmentation’ generally occurs at least once every 5 years.

[0005] For example, conventional pumped hydro suffers from the following deficiencies relating to the above factors:

- Large land use and significant geographic limitations
- Significant environmental damage and permanent environment alteration
- Seismic risk and landslide risk, including the risk of significant economic and / or human tragedy in the event to a significant earthquake, or landslide slide, or both.

[0006] Another challenge in the renewable energy industry is the availability of land for the development of renewable energy projects and / or energy storage projects. In many instances, local, regional, national, and international stakeholders are strongly against the development of undeveloped or ‘untouched’ lands, including the development of renewable energy, such as wind and solar. Stakeholders are often opposed to such development because of the environmental, visual, or noise pollution during the construction and / or operation of wind and / or solar projects. Said opposition has made finding new land, receiving permits, and developing solar and wind projects increasingly difficult and has greatly increased development timelines. As a result, renewable energy project developers have become increasingly interested in the development of renewable energy projects offshore, in the ocean and other large water bodies. The visual impacts of near shore offshore wind farms have also encouraged project developers to look increasingly

further offshore and into deeper water. Interconnecting electricity transmission from offshore wind to the onshore electricity grid has become a significant challenge because of the intermittency of wind and the large capacities of wind power generation requiring interconnection. One potential solution is long duration electricity storage. Most prior art electricity storage technologies are not suitable for the marine environment. For example, the corrosivity of the marine environment and the ability for lithium burn in water, even without the presence of air or oxygen, has deemed lithium ion batteries unsuitable or undesirable for marine environments. There is a significant need for a low cost, scalable, environmentally friendly, low land or water use, long lasting, high round trip energy efficiency long duration electricity storage technology suitable for the offshore environment.

[0007] Additionally, the need for electricity generation and storage technologies to produce electricity reliably, consistently, and long term when needed is becoming increasingly more crucial due to the increasingly common occurrence of extreme and unusual weather due to climate change. Prior art energy storage technologies are unable to provide additional power beyond their nameplate electricity storage capacity, even in the event of an emergency, which has contributed to notable power outages in California and throughout the United States in recent years. For example, if a lithium ion battery or pumped hydro plant is rated at 1,000 MWh, and the 1,000 MWh has been fully used or is fully discharged, the lithium ion battery or pumped hydro plant will be incapable of providing more electricity if more electricity is needed.

[0008] There is a significant need for an electricity storage technology capable of functioning as both a high round trip efficiency (>70%) short, or medium, or long duration electricity storage system and, when needed, a multi-day, or multi-week, or multi-month electricity storage system. There is a significant need for an electricity storage technology capable of functioning as both a high round trip efficiency (>70%) 8+ hour duration electricity storage system and, when needed, a multi-day, or multi-week, or multi-month electricity storage system. There is a significant need for an electricity storage technology capable of functioning as both a high round trip efficiency (>70%) 8+ hour duration electricity storage system and, when needed, a multi-day, or multi-week, or multi-month source of power or electricity.

SUMMARY OF THE INVENTION

[0009] The present invention relates to systems and methods for energy storage, or energy generation, or combinations thereof.

[0010] Some embodiments may be applicable to, for example, an energy storage device. Some embodiments may involve a storage region beneath the surface of a water or liquid body and a

storage region near the surface or above a water or liquid body. To ‘charge’ said energy storage device, low density fluid, such as a relatively lower density liquid or a gas, may be pumped into said storage region, displacing a higher density fluid, such as water. To discharge said energy storage device, said higher density fluid may be allowed to displace said lower density fluid, generating electricity due to the flow of the lower density fluid through an electric generator.

[0011] Some embodiments may solve one or more or all the deficiencies of prior art energy storage systems. For example, some embodiments possess one or more or a combination of the following:

- Low capital cost on a cost per MWh of energy storage capacity and cost per MW of power capacity basis
- High round trip efficiency, such as a round trip efficiency greater than or equal to one or more or a combination of the following: 60%, or 65%, or 70%, or 75%, or 80%, or 85%, or 90%, or 95%, or 99%
- No power capacity degradation over each charge – discharge cycle
- No energy storage capacity degradation over each charge – discharge cycle
- No land use
- Minimal water surface area usage
- Minimal geographic limitation, as 40% of the world’s population lives within 100 km of the coast
- Long lifespan, such as greater than 20 years, or 25 years, or 30 years, or 35 years, or 40 years, or 45 years, or 50 years, or 55 years, or 60 years, or any combination thereof
- Recyclability of most or all components at ‘end-of-life’
- Reusability of most or all components at ‘end-of-life’, which may include, but are not limited to, life extensions or repurposing for other uses.
- Minimal environmental impact of manufacturing and materials of construction
- Minimal environmental impact of construction, installation, and operation
- Significant positive local economic impact
- Just transition for oil & gas workers to the renewable energy industry. For example, some embodiments employ much of the same equipment, such as pipes, vessels, pumps, and materials, such as steel and cement, and skills, except for electricity storage systems for, for example, storing renewable electricity.
- Designed for and / or applicable to aquatic, or marine, or offshore environments

[0012] Some embodiments may be applicable to a system which provides high round trip efficiency electricity storage, and, when needed, can supply fuel and / or electricity for days, or weeks, or months, or years, or any combination thereof. For example, some embodiments may store energy by displacing high density liquid with a low density liquid, wherein the low density liquid or high density liquid or both may comprise a chemical which may alternatively be employed as a fuel. For example, some embodiments may involve storing electricity by displacing a high density liquid with a low density liquid, wherein said displacing energy storage mechanism may store sufficient energy to provide power at maximum system power capacity for greater than or equal to 1 hours, or 2 hours, or 4 hours, or 6 hours, or 8 hours, or 10 hours, or 12 hours, or 14 hours, or 16 hours, or 18 hours, or 20 hours, or 25 hours, or 30 hours or 35 hours, or 40 hours, or 45 hours, or 50 hours, or 75 hours, or 100 hours or any combination thereof. For example, some embodiments may involve storing electricity by displacing a high density liquid with a low density liquid, wherein said displacing energy storage mechanism may store sufficient energy to provide power at maximum system power capacity for less than 50 hours, and wherein the low density liquid, or high density liquid, or both may comprise a fuel and may be capable of providing power for greater than 50 hours, or greater than 75 hours, or greater than 100 hours, or greater than 1 week, or greater than 1 month, if needed. For example, some embodiments may involve storing electricity by displacing a high density liquid with a low density liquid, wherein said displacing energy storage mechanism may store sufficient energy to provide power at maximum system power capacity for a first duration, and wherein the low density liquid, or high density liquid, or both may comprise a fuel and may be capable of providing power for a second duration, when needed. For example, some embodiments may involve storing electricity by displacing a high density liquid with a low density liquid, wherein said displacing energy storage mechanism may store sufficient energy to provide power at maximum system power capacity for a first duration, and wherein the low density liquid, or high density liquid, or both may comprise a fuel and may be capable of providing power for a second duration, when needed, and wherein the said second duration is greater than said first duration.

[0013] Some embodiments may be applicable to ensuring an underwater tank is in pressure equilibrium with the ocean water adjacent to, or surrounding, or at the same elevation as said underwater tank. Some embodiments may be applicable to minimizing the pressure difference between pressure of a fluid inside an underwater tank and the pressure of water or other fluid outside, or adjacent to, or surrounding, or at the same elevation as said underwater tank. For example, some embodiments may relate to the use of a pressure exchanger or power exchanger to

extract excess pressure or power from one fluid and transfer said excess pressure or power to another fluid. For example, some embodiments may relate to the use of a pressure exchanger or power exchanger to extract excess pressure or power from a lower density fluid and transfer said excess pressure or power to a higher density fluid. For example, some embodiments may relate to the use of a pressure exchanger or power exchanger to extract excess pressure or power from a higher density fluid and transfer said excess pressure or power to a lower density fluid. For example, some embodiments may relate to the use of a pressure exchanger or power exchanger to extract excess pressure or power from a higher density fluid and transfer said excess pressure or power to a lower density fluid. For example, some embodiments may relate to the use of a pressure exchanger or power exchanger to extract excess pressure or power from a higher pressure fluid and transfer said excess pressure or power to a lower pressure fluid. For example, some embodiments may relate to the use of a pressure exchanger or power exchanger to extract excess pressure or power from a higher pressure fluid and transfer said excess pressure or power to a lower pressure fluid, wherein said excess pressure may be less than or equal to the difference in pressure between said higher pressure fluid and water adjacent to, or surrounding, or outside of, or at the same elevation as at least a portion of the underwater tank. For example, some embodiments may relate to the use of a pressure exchanger or power exchanger to extract excess pressure or power from a first fluid and transfer said excess pressure or power to a second fluid, wherein said excess pressure may be less than or equal to the difference in pressure between said first fluid and water or other fluid adjacent to, or surrounding, or outside of, or at the same elevation as at least a portion of the underwater tank. For example, some embodiments may relate to the use of a pressure exchanger or power exchanger to extract excess pressure or power from a second fluid and transfer said excess pressure or power to a first fluid, wherein said excess pressure may be less than or equal to the difference in pressure between said second fluid and water or other fluid adjacent to, or surrounding, or outside of, or at the same elevation as at least a portion of the underwater tank. For example, some embodiments may relate to pressure equalizers to enable or ensure pressure equilibrium with water or other fluid adjacent to, or surrounding, or outside of, or at the same elevation as at least a portion of the underwater tank. For example, some embodiments may relate to pressure sensors, or valves, or any combination thereof. For example, some embodiments may relate to systems and methods for minimizing or preventing hydraulic ram or minimizing or preventing potential negative impacts of hydraulic ram. Some embodiments may involve energy storage systems wherein the higher density liquid has a density greater than water or ocean water. Some embodiments may involve energy storage systems wherein at least one

reservoir is located at an elevation greater than the elevation of the surface of a water body, or sea level, or both.

[0014] Some embodiments may be applicable to energy storage systems wherein the lower density liquid, or higher density liquid, or both are volatile or have a low boiling point. For example, some embodiments may be applicable to using a pressurized tank or a tank resilient to a pressure difference. For example, some embodiments may be applicable to locating a tank at a water depth or hydrostatic pressure wherein the pressure difference between pressurized fluids inside a tank and the fluids outside or surrounding or adjacent to said tank is less than if said tank was on land, or surrounded by atmospheric pressure, or both. For example, some embodiments may be applicable to refrigerating, or semi-refrigerating, or cooling, or passively cooling, or actively cooling, or thermally managing, or any combination thereof lower density liquid, or higher density liquid or both. For example, some embodiments may relate to ensuring the low density liquid, or high density liquid, or both are stored at a liquid state. For example, some embodiments may relate to ensuring the low density liquid, or high density liquid, or both are stored at a liquid, or supercritical, or slurry, or any combination thereof state. For example, some embodiments may relate to systems and methods for heat exchanging and / or thermal storage to minimize energy use and / or maximize energy efficiency and / or practicality of refrigerating, or semi-refrigerating, or cooling, or passively cooling, or actively cooling, or thermally managing, or any combination thereof lower density liquid and / or higher density liquid. For example, some embodiments may be applicable to enabling the use of cryogenic liquids. For example, some embodiments may be applicable to enabling the simultaneous storage of energy and the generation of power from ocean thermal energy conversion or from temperature differences in the thermocline of an ocean, or water body, or temperature differences between air and water, or any combination thereof.

[0015] Some embodiments may pertain to tanks applicable to storing low density fluids underwater. For example, some embodiments may relate to rigid or flexible structures. For example, some embodiments may relate to tanks or storage regions containing a porous solid medium, wherein a low density fluid may be stored in the pores of said porous medium. For example, some embodiments may relate to tanks or storage regions containing a porous solid medium, wherein low density fluid is stored in said porous medium by pumping or otherwise directing a low density fluid into said porous medium to displace a higher density fluid stored in said porous medium. For example, some embodiments may employ a storage reservoir comprising a porous medium, wherein the density or weight of said porous medium may reduce the buoyancy of said storage reservoir. For example, some embodiments may employ a storage reservoir

comprising a porous medium, wherein the presence of a solid porous medium prevents the substantial collapse of said reservoir if, for example, the pressure inside the reservoir is less than the pressure outside, or adjacent to, or surrounding, or at the same elevation as said reservoir. For example, some embodiments may employ a storage reservoir comprising a porous medium, wherein the presence of a solid porous medium prevents the substantial collapse of said reservoir if, for example, a fluid is pumped out of or removed from a storage reservoir at a greater volumetric rate than fluid is added to or pumped into a storage reservoir. For example, some embodiments may employ a storage reservoir comprising a porous medium, wherein the presence of a solid porous medium prevents the substantial collapse of said reservoir if, for example, a fluid is pumped out of or removed from a storage reservoir without the simultaneous additional of another fluid to said reservoir. Substantial collapse may comprise a storage reservoir decreasing in total volume by greater than or equal to, one or more or a combination of the following: 1 percent, or 5 percent, or 10 percent, or 15 percent, or 20 percent, or 25 percent, or 30 percent, or 35 percent, or 40 percent, or 45 percent, or 50 percent, or 55 percent, or 60 percent, or 65 percent, or 70 percent, or 75 percent, or 80 percent, or 85 percent, or 90 percent, or 95 percent

[0016] Some embodiments may be applicable to a simultaneous energy storage system and tidal power system. For example, some embodiments may enable the storage of electricity, while also generating power from changes in water level due to tides in the same system. Some embodiments may be applicable to, for example, a tidal power energy generation system, which generates energy from change in water level due to, for example, tides. Some embodiments may involve using the displacement of air or other fluid from a storage region due to a rise in water level due to tides to generate energy, such as electricity. Some embodiments may involve using the movement of air or other fluid into a storage region due to a decrease in water level due to tides to generate electricity. Moving parts for said tidal power system, such as pumps and generators, if desired, may be located entirely above the surface of a water or liquid body.

[0017] Some embodiments may be applicable to, for example, inhibiting or preventing growth formation or fouling of structures in liquid environments on marine structures, which may include, but are not limited to, marine structures designed for the storage of energy, or generation of tidal power, or combinations thereof. Some embodiments may be applicable to, for example, inhibiting or preventing growth formation or fouling of structures in liquid environments. Said liquid environments may comprise aqueous and / or non-aqueous environments. Some embodiments described herein may inhibit or eliminate or prevent growth formation or fouling without the need for coatings, paint, manual cleaning/scrubbing, or other methods described in the art. Growth

formations may include, but are not limited to, one or more or a combination of the following: marine growths, foulants, marine creatures, marine animals, inorganic scaling, organic scaling, barnacles, mussels, clams, oysters, worms, shrimp, crustaceans, biofilms, algae, bacteria, fungi, or ameba. Moving parts for said embodiments related to inhibiting or preventing growth formation or fouling or corrosion of structures in liquid environments, such as pumps and generators, if desired, may be located entirely above the surface of a water or liquid body.

[0018] Some embodiments may be applicable to, for example, increasing or decreasing the height of a floating structure, such as a dock. Some embodiments described herein may involve increasing the height of a floating structure above the surface of a liquid by pumping air into a concave region within or beneath said floating structure such that the air or other gas or other low-density fluid at least partially displaces a portion of water in said concave region. Similarly, the height of a floating structure above the surface of a liquid may be decreased by allowing gas to escape from or by pumping gas out of said concave region. Air or other gas may be transferred in or out of said concave region using one or more tubes. The concave region may be open to the water or other liquid. If advantageous, the pumping or release of gas may be conducted using moving parts entirely outside of the water or liquid body. By having moving parts outside of and not in contact with water or the liquid, the moving parts (e.g. air pump) may comprise lower cost equipment, may be less susceptible to fouling, and may have a longer lifespan.

[0019] It is important to note that embodiments described herein may be combined and the systems and methods described herein may overlap or have multiple simultaneous applications.

BRIEF DESCRIPTION OF DRAWINGS:

[0020] **Figure 1:** An example structure with a concave region ‘gas pocket’ (‘3’) on the bottom of each float or pontoon.

[0021] **Figure 2 (above):** An example structure with a concave region ‘gas pocket’ (‘3’) on the bottom of each float or pontoon with air pump and tube interconnected.

[0022] **Figure 3:** An example embodiment with extended ‘walls’, which may be employed to prevent air or gas losses in the event of, for example, waves, turbulent water, or a significant change in the angle of the dock.

[0023] **Figure 4:** An example embodiment where changing the volume of gas in a gas pocket adjusts the height above the liquid surface and/or angle of a floating structure, such as a dock. Figure 4 may show height increasing.

[0024] **Figure 5:** An example embodiment where changing the volume of gas in a gas pocket adjusts the height above the liquid surface and/or angle of a floating structure, such as a dock.

Figure 5 may show height decreasing.

[0025] **Figure 6:** An example simplified setup of an embodiment employing a lower density liquid and a higher density liquid.

[0026] **Figure 7:** Step 1: Figure 7 may show an energy storage embodiment undergoing charging.

[0027] **Figure 8:** Step 2: Figure 8 may show an energy storage embodiment at a relatively charged state.

[0028] **Figure 9:** Step 3: Figure 9 may show an energy storage embodiment discharging.

[0029] **Figure 10:** Step 4: Figure 10 may show an energy storage embodiment at a relatively discharged state.

[0030] **Figure 11:** Figure 11 may show an example embodiment where the LDL and/or HDL storage regions at a higher head height or above the surface are located on a platform or a floating platform.

[0031] **Figure 12:** Figure 12 may show an example embodiment where the LDL and/or HDL storage regions at a higher head height or above the surface are located on land.

[0032] **Figure 13:** Figure 13 may show an example embodiment where multiple subsurface storage regions are employed for energy storage and / or chemical storage.

[0033] **Figure 14:** Step 1 Figure 14 may show an embodiment where electricity is being generated.

[0034] **Figure 15:** Step 2 Figure 15 may show an embodiment where the storage region is nearly full with water.

[0035] **Figure 16:** Step 3 Figure 16 may show an embodiment generating electricity when the surrounding water body water level is relatively low compared to the water level inside the storage region.

[0036] **Figure 17:** Step 4 Figure 17 may show an embodiment where the storage region is nearly empty with water.

[0037] **Figure 18:** Step 4 Alternative : Figure 18 may show an embodiment where the storage region is fully empty with water.

[0038] **Figure 19:** Step 5 (Lower Tide, Pump remaining water out): Figure 19 may show an embodiment where air is pumped into a storage region to remove or displace residual water.

[0039] **Figure 20:** Step 1 (Higher Tide, Filling, Electricity Generation): Figure 20 shows an example embodiment where water / air cavity or storage region contains a porous material.

[0040] **Figure 21:** Step 2 (High Tide, Cavity Full): Figure 21 shows an example embodiment where water / air cavity or storage region contains a porous material.

[0041] **Figure 22:** Step 3 (Lower Tide, Emptying, Generating Electricity): Figure 22 shows an example embodiment where water / air cavity or storage region contains a porous material.

[0042] **Figure 23:** Step 4 (Lower Tide, Empty): Figure 23 shows an example embodiment where water air cavity or storage region contains a porous material.

[0043] **Figure 24:** Step 1 (Higher Tide, Filling, Generating Electricity): Figure 24 shows an example embodiment where water / air cavity or storage region is located on or within a water body.

[0044] **Figure 25:** Step 2 (Higher Tide, Full): Figure 25 shows an example embodiment where water / air cavity or storage region is located on or within a water body.

[0045] **Figure 26:** Step 3 (Lower Tide, Emptying): Figure 26 shows an example embodiment where water / air cavity or storage region is located on or within a water body.

[0046] **Figure 27:** Alternative Step 3 (Lower Tide, Emptying, Depending on Tide and Location): Figure 27 shows an example embodiment where water / air cavity or storage region is located on or within a water body.

[0047] **Figure 28:** Step 4 (Lower Tide, Empty): Figure 28 shows an example embodiment where water / air cavity or storage region is located on or within a water body.

[0048] **Figure 29:** Figure 29 shows an example embodiment with a floating pump or generator station.

[0049] **Figure 30:** Figure 30 shows an energy storage system where the first storage reservoir is located on land and the pump and / or generator is located on land.

[0050] **Figure 31:** Figure 31 shows an energy storage system where the first storage reservoir is located on land and the pump and / or generator is located on land.

[0051] **Figure 32:** Figure 32 shows an energy storage system where the first storage reservoir is located near, at, or beneath the surface of a water body and/or the pump and / or generator is located near, at or beneath the surface of a water body.

[0052] **Figure 33:** Figure 33 shows an energy storage system where the first storage reservoir is located near, at, or beneath the surface of a water body and/or the pump and / or generator is located near, at or beneath the surface of a water body.

[0053] **Figure 34** is an embodiment of low density fluid displacement.

- [0054] **Figure 35** is an embodiment of low density fluid displacement.
- [0055] **Figure 36** is an embodiment of low density fluid displacement.
- [0056] **Figure 37** is an embodiment of low density fluid displacement.
- [0057] **Figure 38** is an embodiment of low density fluid displacement.
- [0058] **Figure 39** is an embodiment of low density fluid displacement.
- [0059] **Figure 40** is an embodiment of low density fluid displacement.
- [0060] **Figure 41** is an embodiment of low density fluid displacement.
- [0061] **Figure 42** is an embodiment of low density fluid displacement.
- [0062] **Figure 43** is an embodiment of low density fluid displacement.
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- [0065] **Figure 46** is an embodiment of low density fluid displacement.
- [0066] **Figure 47** is an embodiment of low density fluid displacement.
- [0067] **Figure 48** is an embodiment of low density fluid displacement.
- [0068] **Figure 49** is an embodiment of low density fluid displacement.
- [0069] **Figure 50** is an embodiment of low density fluid displacement.
- [0070] **Figure 51** is an embodiment of low density fluid displacement.
- [0071] **Figure 52** is an embodiment of low density fluid displacement.
- [0072] **Figure 53** is an embodiment of low density fluid displacement.
- [0073] **Figure 54** is an embodiment of low density fluid displacement.
- [0074] **Figure 55** is an embodiment of low density fluid displacement.
- [0075] **Figure 56** is an embodiment of low density fluid displacement.
- [0076] **Figure 57** is an embodiment of low density fluid displacement.
- [0077] **Figure 58** is an embodiment of low density fluid displacement.
- [0078] **Figure 59** is an embodiment of low density fluid displacement.
- [0079] **Figure 60** is an embodiment of low density fluid displacement.
- [0080] **Figure 61** is an embodiment of low density fluid displacement.
- [0081] **Figure 62** is an embodiment of low density fluid displacement.
- [0082] **Figure 63** is an embodiment of low density fluid displacement.
- [0083] **Figure 64** is an embodiment of low density fluid displacement.
- [0084] **Figure 65** is an embodiment of low density fluid displacement.
- [0085] **Figure 66** is an embodiment of low density fluid displacement.
- [0086] **Figure 67** is an embodiment of low density fluid displacement.

- [0087] **Figure 68** is an embodiment of low density fluid displacement.
- [0088] **Figure 69** is an embodiment of low density fluid displacement.
- [0089] **Figure 70** is an embodiment of low density fluid displacement.
- [0090] **Figure 71** is an embodiment of low density fluid displacement.
- [0091] **Figure 72** is an embodiment of low density fluid displacement.
- [0092] **Figure 73** is an embodiment of low density fluid displacement.
- [0093] **Figure 74** is an embodiment of low density fluid displacement.
- [0094] **Figure 75** is an embodiment of low density fluid displacement.
- [0095] **Figure 76** is an embodiment of low density fluid displacement.
- [0096] **Figure 77** is an embodiment of low density fluid displacement.
- [0097] **Figure 78** is an embodiment of low density fluid displacement.
- [0098] **Figure 79** is an embodiment of low density fluid displacement.
- [0099] **Figure 80** is an embodiment of low density fluid displacement.
- [0100] **Figure 81** is an embodiment of low density fluid displacement.
- [0101] **Figure 82** is an embodiment of low density fluid displacement.
- [0102] **Figure 83** is an embodiment of low density fluid displacement.
- [0103] **Figure 84** is an embodiment of low density fluid displacement.
- [0104] **Figure 85** is an embodiment of low density fluid displacement.
- [0105] **Figure 86** is an embodiment of low density fluid displacement.
- [0106] **Figure 87** is an embodiment of low density fluid displacement.
- [0107] **Figure 88** A process for energy storage storing electricity by displacing a high density liquid with a low density liquid and employing cold and warm supplemental thermal storage.
- [0108] **Figure 89** A process for energy storage generating electricity by displacing a low density liquid with a high density liquid and employing cold and warm supplemental thermal storage.
- [0109] **Figure 90** A process for energy storage storing electricity by displacing a high density liquid with a low density liquid and employing cold and warm supplemental thermal storage and a cooling system.
- [0110] **Figure 91** A process for energy storage generating electricity by displacing a low density liquid with a high density liquid and employing cold and warm supplemental thermal storage and a cooling system.
- [0111] **Figure 92** A process for energy storage storing electricity by displacing a high density liquid with a low density liquid and employing thermal storage and a cooling system.

[0112] **Figure 93** A process for energy storage generating electricity by displacing a low density liquid with a high density liquid and employing thermal storage and a cooling system.

[0113] **Figure 94** A process for energy storage storing electricity by displacing a high density liquid with a low density liquid and employing thermal storage and a cooling system.

[0114] **Figure 95** A process for energy storage generating electricity by displacing a low density liquid with a high density liquid and employing thermal storage and a cooling system.

[0115] **Figure 96** A process for energy storage storing electricity by displacing a high density liquid with a low density liquid and employing thermal storage and a cooling system

[0116] **Figure 97** A process for energy storage generating electricity by displacing a low density liquid with a high density liquid and employing thermal storage and a cooling system.

[0117] **Figure 98** A process for energy storage generating electricity by displacing a low density liquid with a high density liquid and employing thermal storage and a cooling system.

[0118] **Figure 99** A process for energy storage storing electricity by displacing a high density liquid with a low density liquid and employing thermal storage and a cooling system

[0119] **Figure 100** A process for energy storage with the higher elevation reservoir located on land and the lower elevation reservoir located underwater.

[0120] **Figure 101** A process for energy storage with the higher elevation reservoir located on land and the lower elevation reservoir located underwater.

[0121] **Figure 102** A process for energy storage with the higher elevation reservoir located underwater near or on a seabed and the lower elevation reservoir located underwater near or on a seafloor.

[0122] **Figure 103** A process for energy storage with the higher elevation reservoir located underwater near or on a seabed and the lower elevation reservoir located underwater near or on a seafloor.

[0123] **Figure 104** A process for energy storage with the higher elevation reservoir located on the water as a semi-submersible or fully submersed or combination thereof vessel and the lower elevation reservoir located underwater near or on a seafloor.

[0124] **Figure 105** A process for energy storage with the higher elevation reservoir located on the water as a semi-submersible or fully submersed or combination thereof vessel and the lower elevation reservoir located underwater near or on a seafloor.

[0125] **Figure 106** A process for energy storage with the higher elevation reservoir comprising a floating vessel and the lower elevation reservoir located under water near or on the seafloor.

[0126] **Figure 107** A process for energy storage with the higher elevation reservoir comprising a floating vessel and the lower elevation reservoir located under water near or on the seafloor.

[0127] **Figure 108** A process for energy storage with a lower elevation reservoir underwater and / or above and / or on the seafloor.

[0128] **Figure 109** A process for energy storage with a lower elevation reservoir underwater and / or above and / or on the seafloor.

[0129] **Figure 110** A process for energy storage with a lower elevation reservoir underwater and / or above and / or on the seafloor.

[0130] **Figure 111** A process for energy storage with a lower elevation reservoir underwater and / or above and / or on the seafloor.

[0131] **Figure 112** A process for energy storage with a lower elevation reservoir underwater and / or underground beneath the seafloor or buried or a combination thereof.

[0132] **Figure 113** A process for energy storage with a lower elevation reservoir underwater and / or underground beneath the seafloor or buried or a combination thereof.

[0133] **Figure 114** A process for energy storage with a lower elevation reservoir underwater and / or underground beneath the seafloor or buried or a combination thereof.

[0134] **Figure 115** A process for energy storage with a lower elevation reservoir underwater and / or underground beneath the seafloor or buried or a combination thereof.

[0135] **Figure 116** A process for energy storage with a lower elevation reservoir underground.

[0136] **Figure 117** A process for energy storage with a lower elevation reservoir underground.

[0137] **Figure 118** A process for energy storage with a lower elevation reservoir underground.

[0138] **Figure 119** A process for energy storage with a lower elevation reservoir underground.

[0139] **Figure 120** A process for energy storage which is configured to store both low density liquid and high density liquid in a higher elevation reservoir.

[0140] **Figure 121** A process for energy storage which is configured to store both low density liquid and high density liquid in a higher elevation reservoir.

[0141] **Figure 122** A process for energy storage which is configured to store both low density liquid and high density liquid in a higher elevation reservoir.

[0142] **Figure 123** A process for energy storage which is configured to store both low density liquid and high density liquid in a higher elevation reservoir.

[0143] **Figure 124** A process for energy storage which is configured to store both low density liquid and high density liquid in a higher elevation reservoir and wherein the higher elevation reservoir is a floating structure.

[0144] **Figure 125** A process for energy storage which is configured to store both low density liquid and high density liquid in a higher elevation reservoir and wherein the higher elevation reservoir is a floating structure.

[0145] **Figure 126** A process for energy storage which is configured to store both low density liquid and high density liquid in a higher elevation reservoir and wherein the higher elevation reservoir is a floating structure.

[0146] **Figure 127** A process for energy storage which is configured to store both low density liquid and high density liquid in a higher elevation reservoir and wherein the higher elevation reservoir is a floating structure.

[0147] **Figure 128** A process for energy storage which is configured to store both low density liquid and high density liquid in a higher elevation reservoir and employs thermal storage.

[0148] **Figure 129** A process for energy storage which is configured to store both low density liquid and high density liquid in a higher elevation reservoir and employs thermal storage.

[0149] **Figure 130** A process for energy storage which is configured to store both low density liquid and high density liquid in a higher elevation reservoir and employs thermal storage.

[0150] **Figure 131** A process for energy storage which is configured to store both low density liquid and high density liquid in a higher elevation reservoir and employs thermal storage.

[0151] **Figure 132** A process for energy storage which is configured to store both low density liquid and high density liquid in a higher elevation reservoir and employs thermal storage.

[0152] **Figure 133** A process for energy storage which is configured to store both low density liquid and high density liquid in a higher elevation reservoir and employs thermal storage.

[0153] **Figure 134** A process for energy storage which is configured to store both low density liquid and high density liquid in a higher elevation reservoir and employs thermal storage and a thermal management system.

[0154] **Figure 135** A process for energy storage which is configured to store both low density liquid and high density liquid in a higher elevation reservoir and employs thermal storage and a thermal management system.

[0155] **Figure 136** A process for energy storage which is configured to store both low density liquid and high density liquid in a higher elevation reservoir with example flow rates.

[0156] **Figure 137** A process for energy storage which is configured to store both low density liquid and high density liquid in a higher elevation reservoir with example flow rates.

- [0157] **Figure 138** A process for energy storage which is configured to store both low density liquid and high density liquid in a higher elevation reservoir and employs cooling from cooling water or ocean water or deep ocean water.
- [0158] **Figure 139** A process for energy storage which is configured to store both low density liquid and high density liquid in a higher elevation reservoir and employs cooling from cooling water or ocean water or deep ocean water.
- [0159] **Figure 140A** A process for energy storage with a pressure exchanger with thermal management, or cooling, or refrigeration.
- [0160] **Figure 140B** A process for energy storage with a pressure exchanger with thermal management, or cooling, or refrigeration.
- [0161] **Figure 140C** A process for energy storage with a pressure exchanger without thermal management, or cooling, or refrigeration.
- [0162] **Figure 141A** A process for energy storage with a pressure exchanger with thermal management, or cooling, or refrigeration.
- [0163] **Figure 141B** A process for energy storage with a pressure exchanger with thermal management, or cooling, or refrigeration.
- [0164] **Figure 141C** A process for energy storage with a pressure exchanger without thermal management, or cooling, or refrigeration.
- [0165] **Figure 142A** A process for energy storage with a pressure exchanger housed in one unit with thermal management, or cooling, or refrigeration.
- [0166] **Figure 142B** A process for energy storage with a pressure exchanger housed in one unit without thermal management, or cooling, or refrigeration.
- [0167] **Figure 143A** A process for energy storage with a pressure exchanger housed in one unit with thermal management, or cooling, or refrigeration.
- [0168] **Figure 143B** A process for energy storage with a pressure exchanger housed in one unit without thermal management, or cooling, or refrigeration.
- [0169] **Figure 144** A process for energy storage employing a mechanism to remove or separate a portion of low density liquid present in the high density liquid.
- [0170] **Figure 145** A process for energy storage with a countercurrent heat exchanger.
- [0171] **Figure 146** A process for energy storage with a countercurrent heat exchanger.
- [0172] **Figure 147** A process for energy storage with a countercurrent heat exchanger and additional supplemental cooling.

[0173] **Figure 148** A process for energy storage with a first, second and third reservoir, wherein the elevation of the first and third reservoirs are greater than the second reservoir and the elevation of the first reservoir is different from the elevation of the third reservoir.

[0174] **Figure 149** A process for energy storage with a first, second and third reservoir, wherein the elevation of the first and third reservoirs are greater than the second reservoir and the elevation of the first reservoir is different from the elevation of the third reservoir.

[0175] **Figure 150** A process for energy storage with a first, second and third reservoir, wherein the elevation of the first and third reservoirs are greater than the second reservoir and the elevation of the first reservoir is different from the elevation of the third reservoir.

[0176] **Figure 151** A process for energy storage with a first, second and third reservoir, wherein the elevation of the first and third reservoirs are greater than the second reservoir and the elevation of the first reservoir is different from the elevation of the third reservoir.

[0177] **Figure 152** A subsea or underwater or under a body of liquid tank comprising a rigid tank and a pressure equalizer.

[0178] **Figure 153** A subsea or underwater or under a body of liquid tank comprising a rigid tank and a pressure equalizer.

[0179] **Figure 154** A process for energy storage with a pressure exchanger.

[0180] **Figure 155** A process for energy storage with a pressure exchanger.

[0181] **Figure 156** A process for energy storage with a pressure exchanger.

[0182] **Figure 157** A process for energy storage with a pressure exchanger.

[0183] **Figure 158** A process for energy storage with a pump providing supplemental pressure.

[0184] **Figure 159** A process for energy storage with a pump providing supplemental pressure.

[0185] **Figure 160** A process for energy storage with a pressure exchanger.

[0186] **Figure 161** A process for energy storage with a pressure exchanger.

[0187] **Figure 162** A process for energy storage with a pressure exchanger and a second reservoir at a different elevation than a third reservoir.

[0188] **Figure 163** A process for energy storage with a pressure exchanger and a second reservoir at a different elevation than a third reservoir.

[0189] **Figure 164** A process for energy storage with a lower elevation reservoir comprising separate storage for a high density liquid than low density liquid and wherein at least a portion of displacement is provided by a pressure exchanger.

[0190] **Figure 165** A process for energy storage with a lower elevation reservoir comprising separate storage for a high density liquid than low density liquid and wherein at least a portion of displacement is provided by a pressure exchanger.

DETAILED DESCRIPTION OF THE INVENTION

[0191] **Example Energy Storage Embodiments Overview:** Introduced are systems, and methods for energy storage and/or simultaneous oil or chemical storage. In some embodiments, energy is stored via a hydrostatic pressure difference between one or more insoluble or low solubility fluids, which may be driven by a density difference between the one or more fluids. The technology may employ the depth of water bodies to, for example, enable this hydrostatic pressure. An embodiment may comprise, for example, a relatively high density liquid, and a relatively low density liquid or fluid, which may have a lower density than the relatively high density liquid. The end-to-end technology may be a closed system or may be at least closed beneath the surface of the water body. In some embodiments, all or almost all moving parts above the surface of the water body, such as ocean or lake, or, advantageously, not have moving parts, or not have essential moving parts or not have relatively costly moving parts, under water or deep under water, or no moving parts at a depth greater than 250 ft under water, or no moving parts at a depth greater than 1000ft under water. It may be beneficial for the system to be a closed system, wherein the internal fluids, for example high density and low density liquids, are in direct contact with each other. The internal fluids may be separate from or substantially not in contact with the surrounding water body. The water in the water body may simply be employed to ensure pressure, for example liquid pressure, is in equilibrium between the inside fluids and surrounding or external water body. An equilibrium in pressure between the outside and inside of the vessel may enable, for example, the use of lower cost materials, as, for example, at least a portion of the materials may not require resistance to pressure differences or substantial differences. Energy may be stored in the hydrostatic pressure difference between the media (for example: liquids) inside the vessel, for example, wherein one or more media have a higher hydrostatic pressure than another one or more media. Difference in hydrostatic pressure may be driven by the difference in hydrostatic pressure of liquids of difference densities at the same hydraulic head height. An embodiment may comprise media comprising two or more immiscible or low solubility liquids with different densities. The difference in density between two or more liquids at the same or similar height may drive the hydrostatic pressure difference. Advantageously, the process may operate with greater than 70% or 80% round-trip efficiency due to the incompressibility of liquids and high efficiency of hydroelectric generators.

[0192] Embodiments may employ liquids, solids, gases, supercritical fluids or other media phases. One or more phases may be advantageously employed, for example, because said integrated system may be a closed system. For example, in a closed system, contamination with the surrounding water body may not be a challenge, unless, for example, there is a leak.

[0193] In one embodiment, liquid storage of a higher density liquid (such as water) and liquid storage of a lower density liquid (such butane) are placed at a relatively higher head height than a separate liquid-liquid interface vessel or vessels. Said relatively higher head height may be including, but not limited to, one or more of a combination thereof: located lesser depth in the surface of a water body, at the surface of a water body, above the surface of a water body, floating on the surface of a water body, located on land adjacent to a water body, or located on another water body, or located on land. It may be desirable for the higher density liquid to have the same or similar density as the surrounding water body at the same depth. For example, if the pipe or container containing the high density and low density liquids are in ocean, the higher density liquid may comprise a liquid of the same or similar or relatively close density as the surrounding water body or other surrounding media. Alternatively, the higher density liquid may significantly differ in density from the surrounding water body or other surrounding media, as in such an embodiment, pressure difference resistant materials may be required. Separate liquid-liquid interface storage vessel or vessels may be located at a lower head height than the liquid storage. Said liquid-liquid interface storage vessel or vessels may be connected to the higher head height liquid storage vessel or vessels using one or more tubes. Tubes may be employed to transport the lower density liquid or the higher density liquid or a combination thereof. One or more tubes may be connected to one or more valves or pumps or sealed connecting joints. For example, the lower density liquid may be connected to liquid tube or tubes, which may be connected to one or more pumps or generators or connected to low density liquid storage or a combination thereof. For example, the higher density liquid may be connected to liquid tube or tubes, which may be connected to one or more pumps or generators or connected to higher density liquid storage or a combination thereof.

[0194] Storing energy may involve, for example, pumping the lower density liquid into a tube or tubes, displacing at least a portion of the higher density liquid out of the tube or tubes and underwater vessel or vessels into the higher density liquid storage or, alternatively, displacing the higher density liquid into the surrounding water body. Energy may be stored energy due to the difference in hydrostatic pressure between the low-density liquid and high density liquid at the same hydraulic head height – for example, as the low density is pumped into the tubing or storage vessel, it is overcoming the hydrostatic pressure of the higher density liquid, developing a

hydraulic head. When the storage device stops charging, a valve may be employed to prevent the one or more liquids from undesirably reversing flow direction.

[0195] A check valve may be employed during pumping operation to prevent the low-density liquid from reversing pumping direction. Energy storage time-period may indefinite if there are no leaks. During discharge, one or more valves may open, enabling the pressurized low-density liquid to be at least partially displaced and enable said low density liquid to power a generator. Valves, pumps, generators, and other moving parts may be located at the surface or just below the surface, or on land, or a combination thereof as this may reduce capital, operational, and/or maintenance costs.

[0196] In another embodiment, the process may be an open system, wherein the higher density fluid is comprises the fluid in one or more liquid or water bodies, such as, for example, water or salt water or oil or relatively inexpensive liquid. For charging, the low density liquid may be pumped into one or more vessels, displacing the higher density water or liquid in the vessel. The process may contaminate the water in the bay, although this may be minimized by, including, but not limited to, minimizing mixing, preventing the contaminant liquid level, for example the low density liquid level, from approaching or surpassing the edge of the vessel, using a low solubility or insoluble combination of liquids or media, using a non-hazardous or inexpensive low density liquid, or a combination thereof. In the present embodiment, a high density liquid storage vessel may be unnecessary, potentially reducing capital cost and complexity. A version of the present embodiment may comprise an upside down barrel with a tube opening on the inside of the closed, upward facing side of the barrel and a port open to the surrounding liquid body (for example, water body or ocean or lake) on the bottom facing side of the barrel. A version of the present embodiment may comprise an upside down barrel with a tube connected to a liquid tight port connected to upward facing side of the barrel and a port open to the surrounding liquid body (for example, water body or ocean or lake) on the bottom facing side of the barrel. A version of the present embodiment may not contain any liquid tight ports – a tube may be fed into the open side of the up-side-down vessel or barrel and attached to the bottom (inside of top of barrel because up-side-down) of the inside of the vessel or barrel. Advantages of said alternative embodiment include, but are not limited to, a simplified construction, higher pressure resistance, lower opportunity for leak or contamination, and low cost. One or more vessels or barrels may be further connected to a weight or anchor and the upper region of the barrel may be connected to floatation to maintain the one or more vessels or barrels in the desired position (for example, the upside-down position). One or more tubes may be further connected to a pump or generator, which may be further, connected to

one or more low density fluid storage vessels. Said one or more lower density liquids (or other fluid, such as a gas) storage vessels may be located at a higher head height, for example, near the surface, at the surface, or above the surface of the water body. During charging, the lower density liquid (or other fluid, such as a gas) may be pumped into the vessel, displacing the higher density liquid. During discharging, low density liquid may be pumped into the vessel, displacing the higher density liquid.

Pressure of Low Density Liquid:

[0197] The pressure of the low density liquid when the liquid is forced to displace higher density liquid, as is the case when energy is stored, may be at a higher pressure than the surrounding water body, wherein the pressure difference between the low density liquid and the surrounding water body increases with decreasing depth. At the interface between the lower and higher density liquids, the pressure of the two liquids may be equal or close to equal. As the depth of the lower density liquid decreases (or the higher the low density liquid is above the liquid-liquid interface), the greater the lower density liquid deviates in pressure from the higher density liquid or the greater the net pressure of the low density liquid. As a result, the tube or other vessel transporting the lower density liquid across depths or head heights may require pressure resistance, the pressure resistance requirement may increase with decreasing depth (or greater hydraulic height from the liquid-liquid interface or deepest point). The point of the pump or generation may comprise the highest pressure in the embodiment. One way of describing this phenomenon is:

[0198] If an open tube is placed vertically in a water body, the water inside the tube, although separated, is predominately at the same pressure as the surrounding water body at any given depth because the water pressure applied by the water inside the tube above a given point in the tube is the same as the water surrounding the tube. Similarly, when a liquid of different density, such as a lower or higher density, is placed in a closed bottom vessel in open air, the pressure of the liquid at any given point may be equivalent to the liquid pressure applied by the liquid above a point in the liquid. At the same height or depth, a liquid of lower density may have a significantly lower gravitationally derived pressure than a liquid of higher density. When a lower density liquid is displacing a higher density liquid (for example, due to the application of an outside force) in a location experiencing gravity, the net pressure or pressure difference experienced by the lower density liquid at any given height above the liquid-liquid interface or deepest point of the low density liquid is:

$$P_{Net} = P_{HD} - P_{LD}$$

Wherein:

- ' P_{Net} ' may be the Net Pressure of Lower Density Liquid at a Given Height above the Lowest Depth of the Lower Density Liquid or Liquid – Liquid Interface
- ' P_{HD} ' may be the Gravitational Pressure Head of Higher Density Liquid at the Height Above Lowest Depth of Low Density Liquid or Liquid – Liquid Interface
- ' P_{LD} ' may be the Gravitational Pressure Head of Lower Density Liquid at Height Above Lowest Depth of Low Density Liquid or Liquid – Liquid Interface

[0199] **Figure 6:** Figure 6 shows a simplified setup of an embodiment employing a lower density liquid and a higher density liquid. The two boxes with black text are the higher head height liquid storage vessels. The higher head height liquid storage region is connected via tubes or pipes to one or more separate storage vessels. In Figure 6, the tubes are connected to a single storage vessel at a head height below the surface of the liquid body (such as a water body) and located at a head height below the higher head height liquid storage vessels, which may be referred to as the lower head height storage vessel. The higher density liquid tube or pipe is connected to one or more ports at the bottom of the lower head height storage vessel. The lower density liquid tube or pipe is connected to one or more ports at the top of the lower head height storage vessel. It is important to note the location of placement of ports on the lower head height storage vessel may not be of importance, and ports may be placed, in, including, but not limited to: next to each other, across from each other vertically, across from each other horizontally, placed randomly, or in another configuration or in a combination thereof. It may be important for the ports to be liquid tight. An exception may be, for example, if the heavy liquid port is open to the surrounding water bay, potentially eliminating the need for a liquid tight port for the higher density liquid and potentially eliminating the need for a high density liquid pipe or storage vessel. The region inside the lower head height vessel where the higher density liquid and lower density liquid meet may be referred to as the fluid-fluid or liquid-liquid interface. The liquids may be contacted directly, in which case it may be desirable for the liquids to be immiscible. The liquids may also be spaced or separated or constitute non-contiguous liquids by a separator or drum, including, but not limited to, a drum or floating drum. If a floating drum is employed to separate the higher density liquid from the lower density liquid, it may be desirable for the floating drum to be of lower density than the higher density liquid and higher density than the lower density liquid. A liquid-liquid separator or drum may be employed, for example, to reduce liquid-liquid mixing (especially important for soluble liquids) or, in the case where open water is the high density liquid higher density liquid, reduce environmental contamination. Energy is storage by pumping the lower density liquid into

the lower density liquid tube or pipe, which may displace the higher density liquid from the lower head height storage vessel. Stored energy may be released by enabling the displaced water to enter the lower head height vessel, which may displace the lower head height liquid and generate electricity. In the configuration shown in Figure 1, the pump / generator is shown connected to the lower density liquid pipe or tube, which may enable higher pumping efficiency. Pump may be above the water surface, enabling no moving parts to be under water. The lower density liquid may be under pressure during charging and discharging.

[0200] A pump / generator may be connected to the higher density liquid. One potential challenge of pumping the higher density liquid directly is charging may require the formation of a partial vacuum, which may be less efficient and, even in the case of a pure vacuum, may not be enough driving force to remove sufficient higher density liquid from the lower head height vessel. It may be desirable for the pump or generator to be beneath the water line, for example, if the pump or generator is directly in contact or pumping the higher density liquid.

[0201] Liquid storage regions may comprise tanks or reservoirs storing the lower density liquid or higher density liquid. Substantially immiscible or insoluble may mean a liquid which is less than 50 weight percent (wt%), or less than 40wt%, or less than 30wt%, or less than 20wt% soluble in the other liquid.

[0202] It may be advantageous for the higher density liquid storage region to be beneath the water line or at the same or similar or lower depth than the liquid-liquid interface or lowest point of the lower density liquid. This may be advantageous, for example, if the higher density liquid has the same density as the liquid body, such as water body, surrounding the energy storage device. The higher density liquid storage region may comprise, for example, a bladder-like storage device in pressure equilibrium with the surrounding liquid body, such as water body. The higher density liquid storage region may comprise, for example, a storage device with a floating or movable roof in pressure equilibrium with the surrounding liquid body, such as water body.

[0203] The lower head height vessel may be pressure difference resistant. The pressure resistance required by the lower head height vessel may increase with vertical distance from the liquid-liquid interface or lowest point of the lower density liquid. It may be advantageous to minimize the vertical height of the vessel, minimizing the pressure difference experienced by the lower head height vessel compared. This may transition more or most of the lower density liquid pressure difference to the pipe / tube. It may be advantageous to progressively increase the reinforcement of the lower head height vessel with increasing vertical distance from the liquid-liquid interface or the lowest point of the lower density liquid. For example, the structure of

progressively increasing the reinforcement of the lower head height vessel may be similar to water towers, wherein the vessel is progressively more pressurize resistant and reinforced with higher hydrostatic pressure.

[0204] The higher density liquid storage and lower density liquid storage may be, for example, located beneath the surface, floating on the surface, or on land. In some embodiments, the higher density liquid storage may comprise the surrounding water body. In some embodiments, the higher density liquid storage may be in a different location than the lower density liquid storage. For example, the higher density liquid storage may be a bladder like expandable and contractible volume storage region beneath the water body surface, while the lower density liquid storage region may be located on land.

[0205] The energy storage device may undergo charging or discharging at any point in storage capacity. For example, if the device is at least a portion charged, it may be discharged. For example, if the device is at least a portion discharged, it may be charged. For example, if the device is fully charged, it may not have the capacity to further charge. For example, if the device is fully discharged, it may not have the capacity to further discharge.

Example Step by Step Description:

[0206] **Figure 7:** Step 1: Figure 7 may show an energy storage device undergoing charging. A liquid pump may pressurize and pump the Lower Density Liquid (LDL) into a pipe connected to the lower head height storage region, which may allow the LDL to displace the higher density liquid (HDL) in the lower head height storage. As HDL is displaced by the LDL, gravitation potential energy may be stored. In Figure 7, HDL may be shown being transferred it to an HDL storage region above the lower head height storage region. The HDL storage region, for example, if it comprises a fluid in equilibrium with the hydrostatic pressure of the surrounding liquid or of the same density as the surround liquid, may be located elsewhere, for example, beneath the surface of the liquid body, or at the same height or depth as the lower head region, or below the depth of the liquid-liquid interface. The pump or pumps may be powered by work, for example, electricity, hydraulic pressure, or mechanical work.

[0207] The LDL may a volatile liquid (such as propane or butane) and the LDL storage region may be closed. Regardless of whether the LDL is volatile, the LDL storage region may be closed to outside air. If the LDL is sufficiently volatile, the headspace gases in the LDL may comprise the LDL in the gas phase. If the LDL has a sufficiently high partial pressure (for example: propane or butane), the LDL storage region may be pressure resistant and comply with the appropriate safety precautions.

[0208] The HDL may be a volatile liquid. The HDL may comprise water. It may be desirable for the HDL storage region to not be open outside air, as biofouling agents and other contaminants may enter. Alternatively, the headspace of the HDL storage region may comprise, for example, filtered or treated air.

[0209] **Figure 8:** Step 2: Figure 8 may show an energy storage device at a relatively charged state. At a charged, or discharge, or when charged, or when at a steady state, a check valve may be employed to prevent liquid from flowing into the LDL tank.

[0210] It may not be advantageous to have LDL enter the higher density liquid region, which may occur, for example, during overcharging if the HDL storage region is located at a higher height relative to the LDL. If this were to occur, for example, the LDL may float to the surface of the HDL storage region if the HDL storage region is at a higher height relative to the LDL liquid-liquid interface. This may be remediated, for example, by removing the LDL from the HDL using, for example, one or more or a combination of the following: decanting, cyclone, coalescer, filter, or other means of phase or liquid-liquid separations. If the LDL forms a gas phase at the conditions in the HDL storage region, the LDL may be separated by, for example, including, but not limited to, one or more or a combination of the following: removing LDL gas from the headspace, compression of headspace gases, cooling headspace gases, gas separation methods, pressure swing adsorption, pressure swing absorption, membrane, distillation, combustion, absorption, or adsorption.

[0211] **Figure 9:** Step 3: Figure 9 may show an energy storage device discharging. HDL may displace LDL in the subsurface storage region, which may result in high pressure LDL passing through a generator, generating electricity, and entering, for example, an LDL storage tank.

[0212] **Figure 10:** Step 4: Figure 10 may show an energy storage device at a relatively discharged state. At a discharged or charged or when charged or when at a steady state, a check valve may be employed to prevent liquid from flowing into the LDL tank.

[0213] **Figure 11:** Figure 11 may show an example embodiment where the LDL and/or HDL storage regions at a higher head height or above the surface are located on a platform or a floating platform. If desired, the only direct interconnected between the energy storage device and land may be a medium for transporting electricity, such as an electric cable.

[0214] **Figure 12:** Figure 12 may show an example embodiment where the LDL and/or HDL storage regions at a higher head height or above the surface are located on land, such as on the shore or on an island.

[0215] Figure 13: Figure 13 may show an example embodiment where multiple subsurface storage regions are employed for energy storage. If there is more than one subsurface storage region, the subsurface storage regions may be interconnected, which may minimize the number of pipes between the higher head height storage region or regions and the lower head height or subsurface storage region or regions.

Example Installation of an Example Embodiment:

1. Connect tubes (lower density liquid tube and higher density liquid tube) to the two ports of a liquid-tight vessel. Tubes may be wrapped in a roll or in another storage configuration.
 - a. The location of the ports may be of importance, and may be located, for example, to minimize mixing. For example, ports may be located near the top of the vessel for the low-density liquid tube connection and near the bottom of the vessel for the higher density liquid tube.
 - b. Tubes may be connected to one or more rolls of tubing
 - c. Tubes or vessels may require withstanding pressure, although in some embodiments only the tube transporting the lower density liquid must withstand substantial pressure differences.
2. Fill the vessel or tubes or both with a liquid at the same or similar density as surrounding water body (for example: if ocean, same density as ocean water, may be salt water or an aqueous solution containing a dense organic additive, such as glycerol or ethylene glycol or propylene glycol. It may be desirable for the liquid to not comprise bio-foulants, scaling agents, or corrosion or degradation causing agents). Alternatively, the liquid may comprise bio-foulants, scaling agents, or corrosion or degradation causing agents, for example raw ocean water or lake water or raw oil storage liquid or raw waste water or other liquid. The liquid filling the vessel or tubes or both in the present step may be considered the higher density liquid.
3. Attach tubes to their desired storage tank and generator / pump
4. To ensure the vessel remains in the desired position (for example, such as upright) and prevent tangling of tubes, the implementation may involve attaching one or more weights or anchors to near the bottom of the vessel and one or more buoyant floats to near the top of the vessel. The float or near top of the vessel or combination thereof may be further attached to a line, which may be connected by a connector comprising a detachable mechanism, such as clip, or remotely detachable clip.

5. Allow vessel to sink to a desirable depth, for example, near or at the bottom of a water body. Unravel the tubes and lines (for example: the float line and guide line) as the vessel sinks.
6. When the vessel reaches its desired depth (for example: the depth at which the weight or anchor reaches the bottom) the guide line may be detached or may be attached to a float specifying the location.
7. To charge, pump low density liquid into the liquid tubes or vessels, displacing the higher density liquid, which travels through an adjacent tube into a storage vessel. During charging, the low-density liquid may displace the higher density liquid in the tube or in the vessel or in a combination thereof.
8. To discharge, open valve, allowing pressurized low-density liquid (for example: from step 8) to the generator (which may be, for example, a separate generator or may be a pump that can reversibly be used as a generator).

Potential Benefits of Energy Storage Technology Described Herein:

- **>80% round trip efficiency**
 - Liquid pump and generator achieves high efficiency and low thermodynamic losses
- **Unlimited available land area (sits at bottom of water body or ocean)**
- **Unlimited storage time**
- **Unlimited charge / discharge cycles**
 - No moving parts in ocean
 - No degradation or corrosion
 - Reagents do not contact with ocean (water body, such as ocean, is simply used to create depth / head height with same surrounding hydrostatic pressure)
 - Unaffected by marine or water body growths (e.g. barnacles, slimes)
 - Entirely closed system
- **Cost per kWh – Butane costs ~\$300 per m³ liquid**
- **Energy density (at 1000m – 1m³ of butane – water is about 1kWh of electricity)**
- **No environmental impact**
 - Closed system
 - Non -toxic reagents (if a leak were to occur)
- **Abundant, Non-toxic, Non-volatile reagents and building materials**
- **Simple, low cost construction**

- Hydrostatic pressure inside technology may be the same as its surroundings. Enables use of low cost, less pressure resistant materials in construction. (Note: Tube connected to low density liquid may require higher pressure resistance)
- No moving parts in water
- Embodiment may comprise three tanks (two on surface, one on ocean floor), two pipes and one pump / generator

[0216] It may be desirable for the high density liquid (HDL) to have the same density as the surrounding water body liquid. This may enable similar hydrostatic pressure inside the vessel(s) and / or pipes as surrounding the vessel(s) and / or pipes, enabling the potential use of lower cost, less pressure resistant materials.

[0217] To maximize the energy density of the introduced storage device, potentially desirable characteristics, include, but are not limited to, large net density difference (i.e. [density of high density liquid] – [density of ‘low density liquid’]) and low pressure or temperature driven liquid compression (e.g. water minimally compresses under high pressure). An example of this includes, but is not limited to, propane (LDL) and water (HDL)

[0218] To enable effective functionality of the introduced storage device, potentially desirable characteristics, include, but are not limited to, two or more reagents that are substantially insoluble or immiscible. It may be desirable for the high density liquid and low density liquid to be substantially insoluble or immiscible in each other.

[0219] To minimize capital cost, potentially desirable characteristics, include, but are not limited to, low cost reagents, low density for low density liquid, and / or low corrosion or non-corrosive reagents. For example, butane and propane are low cost and liquid at higher pressure operation.

[0220] To minimize capital cost, potentially desirable characteristics, include, but are not limited to, employing materials that are compatible with the reagents inside the integrated process. For example, polypropylene or HDPE is inexpensive, abundant, corrosion resistant, and compatible with water, seawater, butane and propane.

[0221] The energy storage device may also be a means of storing hydrocarbon liquids or chemicals or volatile hydrocarbons. For example, the LDL storage region and lower head height storage region may comprise storage for hydrocarbons, such as, for example, including, but not limited to, crude oil, gasoline, diesel, kerosene, ethane, propane, butane, hexane, octane, cyclopropane, or decane, or a combination thereof. Hydrocarbon liquids are stored in small, medium, or large quantities before they are used or transported in various applications, such as

polymer production, fuel, or other uses. By employing the energy storage device as a simultaneous relatively low density liquid storage device, the capital expense of the hydrocarbon liquids may be avoided. For example, oil & gas companies, hydrocarbon transport companies, oil traders, commodity traders, chemical companies, and other users of hydrocarbons or other relatively low density liquids may employ the present energy storage device as a hydrocarbon liquid storage device. For example, the owners or operators of the energy storage device may be compensated for the storage or service or storing the relatively low density liquids. Although the relatively low density liquids may be purchased, in the present embodiment, the relatively low density liquids may advantageously not be purchased by the owner or operator of the energy storage device. Alternatively, the owner or operator of the energy storage device may be compensated for properly storing the relatively low density liquids. This may eliminate the need to pay the capital expense of purchasing the hydrocarbon liquids, while also developing a new revenue source for storing the hydrocarbon liquids.

[0222] High density liquid may comprise a higher density liquid with limited solubility in water, such as propylene carbonate (density of $\sim 1.2\text{g/cm}^3$) or ethylene glycol diacetate (density of $\sim 1.128\text{g/cm}^3$). With said higher density liquid with limited solubility in water, water may be employed as a low density liquid. Said higher density liquids may be low cost, non-volatile, and relatively non-toxic, enabling their use in large volumes in aquatic or marine environments. Aquatic and marine are used interchangeably herein.

- Ridged storage regions or containers may be employed for the storage region or regions located beneath the surface of the water. Said storage regions may include, but are not limited to, storage containers presently employed to store crude oil or chemicals beneath the surface of the ocean or other water body. Storage regions, including non-ridged or ridged storage regions or containers, may be located outside the water or liquid body. Alternatively or additionally, the storage regions may be located in strategic oil reserves, oil storage, natural gas storage, liquids storage, saline aquifers, geological formations, or oil & gas wells. It may be desirable for one or more storage regions experiencing greater than atmospheric pressure hydrostatic pressure to be in an environment where the surroundings exert a similar or supplemental pressure to minimize the strength requirements and potential cost of a storage region or container. In the case of a solid surroundings, such as a geological formation, such as a salt cavern, the geological formation or artificially constructed geological formation may function to contain or store said liquids directly and may function as a storage region on its own.

EXAMPLE EXEMPLARY EMBODIMENTS:

- An energy storage device comprising:
 - Two or more storage regions
 - Wherein at least one storage region is at a greater pressure than another storage region
 - Wherein energy is stored using the difference in pressure between a lower density liquid and a higher density liquid at the same head height or depth
- An energy storage device comprising:
 - Two or more storage regions
 - Wherein at least one storage region is at a greater pressure than another storage region
 - Wherein said energy storage device is charged by pumping a relatively low density liquid into a storage region to displace a relatively higher density liquid
 - Wherein said energy storage device is discharged by allowing a relatively higher density liquid to displace a relatively lower density liquid and allowing the flow of said lower density liquid to power a generator or hydraulic turbine
- A subsea oil or chemicals storage facility which simultaneously functions as a large-scale energy storage device comprising:
 - Two or more storage regions
 - Wherein at least one storage region is at a greater pressure than another storage region
 - Wherein energy is stored using the difference in pressure between a lower density liquid and a higher density liquid at the same head height or depth
- A subsea oil or chemicals storage facility which simultaneously functions as a large-scale energy storage device comprising:
 - Two or more storage regions
 - Wherein at least one storage region is at a greater pressure than another storage region
 - Wherein said energy storage device is charged by pumping a relatively low density liquid into a storage region to displace a relatively higher density liquid
 - Wherein said energy storage device is discharged by allowing a relatively higher density liquid to displace a relatively lower density liquid and allowing the flow of said lower density liquid to power a generator or hydraulic turbine

- A process for storing energy/electricity while simultaneously storing natural gas comprising
 - Storing natural gas in gas bags or a storage region beneath the surface of a water body
 - Storing electricity compressing or pumping natural gas into said gas bag or storage region, which may expand the volume of said storage region
 - Discharging or generating electricity by allowing said natural gas leave said gas bag or storage region and pass through a generator or turbine
 - Wherein said storage region is connected to a natural gas pipeline or LNG facility or natural gas facility on the surface through one or more tubes or pipes

EXAMPLE EXEMPLARY SUB-EMBODIMENTS:

- Wherein energy is stored in the displacement of a higher density liquid using a lower density liquid under conditions where the pressure head due to gravity of the higher density liquid exceeds the gravitational pressure head of the lower density liquid
- Wherein the pump may function as a generator reversibly
- Wherein one storage region is located beneath the surface of a water body and another storage region is located near or above the surface of a water body
- Wherein said storage regions function as oil or chemicals storage
- Wherein said low density liquid or high density liquid or both are the oil or chemicals requiring storage
- Wherein the storage region beneath the surface of the water body constitutes a higher pressure, lower head height storage region, while the storage region above the surface of a water body constitutes a lower pressure, higher head height region
- Wherein the pump or generator is located near or above the surface of a water body
- Wherein said storage region beneath the surface of a water body contains a concave region with an opening near the bottom of said concave region open to the surrounding water body
- Wherein a drum or separator separates or is located between the lower density liquid and the water from the surrounding water body
- Wherein said storage region beneath the surface of a water body comprises an expandable or contractible or flexible structure, such as a bladder or bag or balloon, which may expand and fill with low density liquid during charging and collapse or contracted or empty during discharging

- Wherein said storage region comprising an expandable or contractible or flexible structure may displace water around said storage region
- Wherein the high density liquid constitutes water or water body surrounding a storage region
- Wherein said storage region beneath the surface of the water body may be anchored or tethered to the ground near the bottom of said water body
- Wherein the pump or generator is in contact with the low-density liquid
- Wherein the pump or generator is in contact with the high-density liquid
- Wherein the pump or generator is located beneath the surface of the water
- Wherein the pump or generator is in contact with the high-density liquid and located near the lower head height, higher pressure storage region
- Wherein, during charging, the high-density liquid is pumped out of a storage region and the lower density liquid replaces the higher density liquid
- Wherein one or more storage regions is employed for the storage of one or more chemicals
- Wherein the low-density liquid or the high density liquid or both comprise the chemicals being stored
- Wherein low-density liquid or high density liquid or both may be added or removed from said system
- Wherein said storage facility / energy storage device is located near an oil platform or chemicals facility
- Wherein a processing unit is employed to separate out residual high density liquid from low density liquid or vice versa before said liquid or liquids are used or transported after removal from said storage region
- Wherein the storage units may be employed for storage of oil or chemicals when excess storage is required
- Wherein the storage units may contain more of, or filled with, or almost fully filled with, or filled with more of low-density liquid to temporarily or semi-permanently or permanently employed for oil or chemical storage, for example, in the event said storage is needed
- Wherein the storage units may contain more of, or filled with, or almost fully filled with, or filled with more of high-density liquid to temporarily or semi-permanently or permanently employed for oil or chemical storage, for example, in the event said storage is needed

- Wherein the system may be optimized to prioritize or balance energy storage or oil storage or chemical storage or a combination thereof depending on, for example, including, but not limited to, one or more or a combination of the following:
 - The amount of chemicals or oil requiring storage
 - The market rate/price for chemical or oil storage
 - The market rate/price of energy storage in the electricity grid
 - The arbitrage value available for energy storage
 - The arbitrage value available for chemical storage
- Wherein the low density liquid is a low density fluid
- Wherein said low density fluid comprises a gas
- Wherein said low density fluid or gas may comprise natural gas
- Wherein said natural gas may be employed in said system for energy generation and oil natural gas storage
- Wherein natural gas may be stored in the form of compressed natural gas (CNG) or liquid natural gas (LNG)
- Wherein said storage region is connected to a natural gas pipeline or LNG facility or natural gas facility on the surface through one or more tubes or pipes
- A process for storing energy/electricity while simultaneously storing natural gas comprising
 - Storing natural gas in gas bags or a storage region beneath the surface of a water body
 - Storing electricity compressing or pumping natural gas into said gas bag or storage region, which may expand the volume of said storage region
 - Discharging or generating electricity by allowing said natural gas leave said gas bag or storage region and pass through a generator or turbine
 - Wherein said storage region is connected to a natural gas pipeline or LNG facility or natural gas facility on the surface through one or more tubes or pipes

[0223] Lower head height, higher pressure storage region may be equivalent to the storage region beneath the surface of a water body

Energy Density (Butane – Water):

Head Height (m)	Potential Energy (Wh per m ³) (One Cycle)
1	1.09
2	2.18
3	3.27
4	4.36
5	5.45
6	6.54
7	7.63
8	8.72
9	9.81
10	10.9
100	109
1000	1090

Liquid Densities

[0224] The table below shows the densities of various example liquids, which may be employed in the technology introduced herein.

Liquid	Temperature - <i>t</i> - (°C)	Density - ρ - (kg/m ³)
Acetic Acid	25	1049
Acetone	25	784.6
Acetonitrile	20	782
Alcohol, ethyl (ethanol)	25	785.1
Alcohol, methyl (methanol)	25	786.5
Alcohol, propyl	25	800.0
Ammonia (aqua)	25	823.5
Aniline	25	1019
Automobile oils	15	880 - 940
Beer (varies)	10	1010
Benzene	25	873.8
Benzil	15	1230
Brine	15	1230
Bromine	25	3120
Butyric Acid	20	959
Butane	25	599
n-Butyl Acetate	20	880
n-Butyl Alcohol	20	810
n-Butylchloride	20	886
Caproic acid	25	921
Carbolic acid (phenol)	15	956
Carbon disulfide	25	1261
Carbon tetrachloride	25	1584
Carene	25	857
Castor oil	25	956.1
Chloride	25	1560
Chlorobenzene	20	1106
Chloroform	20	1489
Chloroform	25	1465
Citric acid, 50% aqueous solution	15	1220
Coconut oil	15	924

Liquid	Temperature - t - (°C)	Density - ρ - (kg/m ³)
Cotton seed oil	15	926
Cresol	25	1024
Creosote	15	1067
Crude oil, 48° API	60°F	790
Crude oil, 40° API	60°F	825
Crude oil, 35.6° API	60°F	847
Crude oil, 32.6° API	60°F	862
Crude oil, California	60°F	915
Crude oil, Mexican	60°F	973
Crude oil, Texas	60°F	873
Cumene	25	860
Cyclohexane	20	779
Cyclopentane	20	745
Decane	25	726.3
Diesel fuel oil 20 to 60	15	820 - 950
Diethyl ether	20	714
o-Dichlorobenzene	20	1306
Dichloromethane	20	1326
Diethylene glycol	15	1120
Dichloromethane	20	1326
Dimethyl Acetamide	20	942
N,N-Dimethylformamide	20	949
Dimethyl Sulfoxide	20	1100
Dodecane	25	754.6
Ethane	-89	570
Ether	25	713.5
Ethylamine	16	681
Ethyl Acetate	20	901
Ethyl Alcohol (Ethanol, pure alcohol, grain alcohol or drinking alcohol)	20	789
Ethyl Ether	20	713
Ethylene Dichloride	20	1253
Ethylene glycol	25	1097
Trichlorofluoromethane refrigerant R-11	25	1476

Liquid	Temperature - t - (°C)	Density - ρ - (kg/m ³)
Dichlorodifluoromethane refrigerant R-12	25	1311
Chlorodifluoromethane refrigerant R-22	25	1194
Formaldehyde	45	812
Formic acid 10% concentration	20	1025
Formic acid 80% concentration	20	1221
Fuel oil	60°F	890
Furan	25	1416
Furforol	25	1155
Gasoline, natural	60°F	711
Gasoline, Vehicle	60°F	737
Gas oils	60°F	890
Glucose	60°F	1350 - 1440
Glycerine	25	1259
Glycerol	25	1126
Heating oil	20	920
Heptane	25	679.5
Hexane	25	654.8
Hexanol	25	811
Hexene	25	671
Hydrazine	25	795
Ionene	25	932
Isobutyl Alcohol	20	802
Iso-Octane	20	692
Isopropyl Alcohol	20	785
Isopropyl Myristate	20	853
Kerosene	60°F	820.1
Linolenic Acid	25	897
Linseed oil	25	929.1
Machine oil	20	910
Mercury		13590
Methane	-164	465
Methanol	20	791
Methyl Isoamyl Ketone	20	888
Methyl Isobutyl Ketone	20	801

Liquid	Temperature - t - (°C)	Density - ρ - (kg/m³)
Methyl n-Propyl Ketone	20	808
Methyl t-Butyl Ether	20	741
N-Methylpyrrolidone	20	1030
Methyl Ethyl Ketone	20	805
Milk	15	1020 - 1050
Naphtha	15	665
Naphtha, wood	25	960
Napthalene	25	820
Nitric acid	0	1560
Ocimene	25	798
Octane	15	698.6
Oil of resin	20	940
Oil of turpentine	20	870
Oil, lubricating	20	900
Olive oil	20	800 - 920
Oxygen (liquid)	-183	1140
Paraffin		800
Palmitic Acid	25	851
Pentane	20	626
Pentane	25	625
Perchlor ethylene	20	1620
Petroleum Ether	20	640
Petrol, natural	60°F	711
Petrol, Vehicle	60°F	737
Phenol (carbolic acid)	25	1072
Phosgene	0	1378
Phytadiene	25	823
Pinene	25	857
Propane	-40	493.5
Propane, R-290	25	494
Propanol	25	804
Propylenearbonate	20	1201
Propylene	25	514.4
Propylene glycol	25	965.3

Liquid	Temperature - t - (°C)	Density - ρ - (kg/m ³)
Pyridine	25	979
Pyrrole	25	966
Rape seed oil	20	920
Resorcinol	25	1269
Rosin oil	15	980
Sea water	25	1025
Silane	25	718
Silicone oil	25	965 - 980
Sodium Hydroxide (caustic soda)	15	1250
Sorbaldehyde	25	895
Soya bean oil	15	924 - 928
Stearic Acid	25	891
Sulfuric Acid 95% concentration	20	1839
Sulfurus acid	-20	1490
Sugar solution 68 brix	15	1338
Sunflower oil	20	920
Styrene	25	903
Terpinene	25	847
Tetrahydrofuran	20	888
Toluene	20	867
Trichlor ethylene	20	1470
Triethylamine	20	728
Trifluoroacetic Acid	20	1489
Turpentine	25	868.2
Water, heavy	11.6	1105
Water - pure	4	1000
Water - sea	77°F	1022
Whale oil	15	925
o-Xylene	20	880

[0225] Low density liquid or high density liquid may be sourced from, for example, waste products. For example, the low density liquid or the high density liquid may be sourced from, for example, including, but not limited to, one or more or a combination of the following: waste cooking oil, waste plastic, waste plastic converted into liquids, waste plastic converted into fuel

oil, waste glycerol, waste alcohol, waste coolant, waste antifreeze, waste lubricant, waste fuel, contaminated oil, contaminated chemicals, or expired goods.

FURTHER DISCUSSION OF SECOND DESCRIPTION OF EMBODIMENTS

[0226] Additional Energy Storage Embodiments Summary

[0227] The present invention pertains to a system for storing energy. The present invention stores energy in the hydrostatic pressure difference between a lesser density liquid and a greater density liquid over the same hydraulic head or depth.

[0228] The present invention may involve storing energy by displacing water or other greater density liquid with a lesser density liquid. Said displacing of water with a lesser density liquid may involve pumping lesser density liquid to a greater depth beneath the surface of water or other body of liquid. Said pumping may consume power, such as electricity, and convert said power into gravitational potential energy and / or energy stored in a hydrostatic pressure difference. Said stored energy may be converted back into power by allowing said lesser density liquid to be released from said greater depth beneath the surface of water or other body of liquid to a lesser depth beneath the surface of water or other body of liquid, passing through a generator in the process.

[0229] Description of Figures

[0230] Figure 30: Figure 30 may show an energy storage system where the first storage reservoir is located on land and the pump and / or generator is located on land. The second storage reservoir is located beneath the surface of a water body at a greater hydrostatic pressure and / or greater depth beneath the surface of a water body than the first storage reservoir. The first storage reservoir, the pump and / or generator, and the second storage reservoir may be connected using pipes. Figure 30 may show the energy storage system undergoing charging. Charging may involve storing power by pumping low density liquid from the first storage reservoir to the second storage reservoir. Storage reservoirs may comprise expandable and / or contractable or collapsible tanks. For example, during charging, the first storage reservoir may contract or collapse into a smaller volume as liquid is pumped from the first storage reservoir to the second storage reservoir. For example, during charging, the second storage reservoir may expand into a larger volume as liquid is pumped from the first storage reservoir to the second storage reservoir.

[0231] Figure 31: Figure 31 may show an energy storage system where the first storage reservoir is located on land and the pump and / or generator is located on land. The second storage reservoir is located beneath the surface of a water body at a greater hydrostatic pressure and / or greater depth beneath the surface of a water body than the first storage reservoir. The first storage

reservoir, the pump and / or generator, and the second storage reservoir may be connected using pipes. Figure 31 may show the energy storage system undergoing discharging. Discharging may involve releasing stored energy by allowing the release of lower density liquid from the first storage reservoir to the second storage reservoir, generating power in the process by allowing said low density liquid to pass through a generator. Storage reservoirs may comprise expandable and / or contractable or collapsible tanks. For example, during discharging, the first storage reservoir may expand into a larger volume as liquid is released from the second storage reservoir to the first storage reservoir. For example, during discharging, the second storage reservoir may contract or collapse into a smaller volume as liquid is released from the second storage reservoir to the first storage reservoir.

[0232] **Figure 32:** Figure 32 may show an energy storage system where the first storage reservoir is located near, at, or beneath the surface of a water body and/or the pump and / or generator is located near, at or beneath the surface of a water body. The second storage reservoir is located beneath the surface of a water body at a greater hydrostatic pressure and / or greater depth beneath the surface of a water body than the first storage reservoir. The first storage reservoir, the pump and / or generator, and the second storage reservoir may be connected using pipes. Figure 32 may show the energy storage system undergoing charging.

[0233] **Figure 33:** Figure 33 may show an energy storage system where the first storage reservoir is located near, at, or beneath the surface of a water body and/or the pump and / or generator is located near, at or beneath the surface of a water body. The second storage reservoir is located beneath the surface of a water body at a greater hydrostatic pressure and / or greater depth beneath the surface of a water body than the first storage reservoir. The first storage reservoir, the pump and / or generator, and the second storage reservoir may be connected using pipes. Figure 33 may show the energy storage system undergoing discharging.

[0234] **Example Figure Keys**

Figure 30	
Diagram Element	Description
1	‘1’ or the first storage reservoir, may comprise a tank or reservoir storing a relatively low density liquid at a lesser hydrostatic pressure than the second storage region, ‘2’. ‘1’ may exist at a pressure at or near the ambient pressure surrounding ‘1’. Alternatively, or additionally, ‘1’ may exist at a pressure greater than ambient pressure surrounding ‘1’, however less than the hydrostatic pressure of the second storage reservoir (‘2’). Alternatively, or additionally, ‘1’ may exist at a pressure less than ambient pressure surrounding ‘1’, which may be less than the

	hydrostatic pressure of the second storage reservoir ('2'). In Figure 30, the process may be undergoing 'charging'. During charging, low density liquid may be pumped from '1' using a pump ('3') to '2'. '2' may be located beneath the surface of a body of liquid with greater density than the low density liquid and/or may exist at a greater hydrostatic pressure than '1'. If '1' comprises a contractable or collapsible tank, the total volume occupied by the tank or total volume of liquid in the tank may decrease during 'charging'.
2	'2' or the second storage reservoir may comprise a tank or reservoir storing a relatively low density liquid at a greater hydrostatic pressure than the first storage region, '1'. '2' may exist at a pressure at or near the ambient pressure surrounding '2'. Alternatively, or additionally, '2' may exist at a pressure greater than ambient pressure surrounding '2' and / or greater than the hydrostatic pressure of the '1'. Alternatively, or additionally, '2' may exist at a pressure less than ambient pressure surrounding '2', which may be greater than the hydrostatic pressure of '1'. In Figure 30, the process may be undergoing 'charging'. During charging, low density liquid may be pumped from '1' using a pump ('3') to '2'. '2' may be located beneath the surface of a body of liquid with greater density than the low density liquid and/or may exist at a greater hydrostatic pressure than '1'. If '2' comprises a contractable or collapsible tank, the total volume occupied by the tank or total volume of liquid in the tank may increase during 'charging'.
3	'3' may comprise a pump and / or generator. '3' may be employed to pump low density liquid from '1' to '2'. '3' may comprise a pump, which may be reversibly employed as a generator. '3' may comprise a pump separate from a generator. '3' may comprise multiple pumps and generators or reversible pump/generators. '3' may act as a valve which separates relatively high pressure low density liquid in the pipe 'Line/Arrow Between '2' and '3'' from the relatively low pressure low density liquid in the pipe 'Line/Arrow Between '1' and '3''. In Figure 30, '3' may be pumping low density liquid from '1' to '2', which may comprise charging the energy storage device.
Electricity	'Electricity' may comprise a source of electricity or an application requiring electricity or both. 'Electricity' may encompass transmission equipment and / or electricity grid infrastructure and / or applications generating or using electricity. In Figure 30, 'Electricity' may involve supplying electricity to '3' to power the pumping of low density liquid from reservoir '1' to reservoir '2'.
Line/Arrow Between '1' and '3'	The present diagram element may comprise a means for transferring low density liquid from '1' to '3'. For example, the present diagram element may comprise a pipe or set of pipes. Said pipe may be compatible with the low density liquid.
Line/Arrow Between '3' and '2'	The present diagram element may comprise a means for transferring low density liquid from '3' to '2'. For example, the

	present diagram element may comprise a pipe or pipes. The present diagram element may involve a pipe which experiences a pressure difference between internal liquid contents and liquid surrounding the pipe. Said pressure difference may vary depending on the depth of the section of pipe beneath the surface of the water body, the depth of reservoir '2' compared to reservoir '1' or to '3', the hydrostatic pressure difference between reservoir '1' and reservoir '2', and/or the density of the low density liquid and/or the density of the liquid surrounding the section of pipe. In Figure 30, the present diagram element may involve transferring low density liquid from '3' to reservoir '2'.
Land	'Land' may comprise a solid structure or surface or earth which '1' and / or '3' are situated in Figure 30. The weight of '1' and / or '3' may be supported by said land in Figure 30.
Water	'Water' may comprise the body of liquid in which reservoir '2' is submerged.

[0235]

Figure 31	
Diagram Element	Description
1	'1' or the first storage reservoir, may comprise a tank or reservoir storing a relatively low density liquid at a lesser hydrostatic pressure than the second storage region, '2'. '1' may exist at a pressure at or near the ambient pressure surrounding '1'. Alternatively, or additionally, '1' may exist at a pressure greater than ambient pressure surrounding '1', however less than the hydrostatic pressure of the second storage reservoir ('2'). Alternatively, or additionally, '1' may exist at a pressure less than ambient pressure surrounding '1', which may be less than the hydrostatic pressure of the second storage reservoir ('2'). In Figure 31, the process may be undergoing 'discharging'. During discharging, low density liquid may be released from '2' to '1', generating electricity by powering generator '3'. '2' may be located beneath the surface of a body of liquid with greater density than the low density liquid and/or may exist at a greater hydrostatic pressure than '1'. If '1' comprises a contractable or collapsible tank, the total volume occupied by the tank or total volume of liquid in the tank may increase during 'discharging'.
2	'2' or the second storage reservoir may comprise a tank or reservoir storing a relatively low density liquid at a greater hydrostatic pressure than the first storage region, '1'. '2' may exist at a pressure at or near the ambient pressure surrounding '2'. Alternatively, or additionally, '2' may exist at a pressure greater than ambient pressure surrounding '2' and / or greater than the hydrostatic pressure of the '1'. Alternatively, or additionally, '2' may exist at a pressure less than ambient pressure surrounding '2', which may be greater than the hydrostatic pressure of '1'. In Figure 31, the process may be undergoing 'discharging'. During

	discharging, low density liquid may be released from '2' to '1', generating electricity by powering generator '3'. '2' may be located beneath the surface of a body of liquid with greater density than the low density liquid and/or may exist at a greater hydrostatic pressure than '1'. If '2' comprises a contractable or collapsible tank, the total volume occupied by the tank or total volume of liquid in the tank may decrease during 'discharging'.
3	'3' may comprise a pump and / or generator and / or valve. '3' may be employed to generate power from low density liquid transferred from '2' to '1' during discharging. '3' may be employed to pump low density liquid from '1' to '2' during charging. '3' may comprise a pump, which may be reversibly employed as a generator. '3' may comprise a pump separate from a generator. '3' may comprise multiple pumps and generators or reversible pump/generators. '3' may act as a valve which separates relatively high pressure low density liquid in the pipe 'Line/Arrow Between '2' and '3'' from the relatively low pressure low density liquid in the pipe 'Line/Arrow Between '1' and '3''. In Figure 31, '3' may be generating power from the release of low density liquid from '2' to '1', which may comprise discharging the energy storage device.
Electricity	'Electricity' may comprise a source of electricity or an application requiring electricity or both. 'Electricity' may encompass transmission equipment and / or electricity grid infrastructure and / or applications generating or using electricity. In Figure 31, 'Electricity' may comprise electricity generated by '3' during discharging and / or the transmission and / or utilization of said electricity.
Line/Arrow Between '1' and '3'	The present diagram element may comprise a means for transferring low density liquid from '3' to '1'. For example, the present diagram element may comprise a pipe or set of pipes. Said pipe may be compatible with the low density liquid.
Line/Arrow Between '3' and '2'	The present diagram element may comprise a means for transferring low density liquid from '2' to '3'. For example, the present diagram element may comprise a pipe or pipes. The present diagram element may involve a pipe which experiences a pressure difference between internal liquid contents and liquid surrounding the pipe. Said pressure difference may vary depending on the depth of the section of pipe beneath the surface of the water body, the depth of reservoir '2' compared to reservoir '1' or to '3', the hydrostatic pressure difference between reservoir '1' and reservoir '2', and/or the density of the low density liquid and/or the density of the liquid surrounding the section of pipe. In Figure 31, the present diagram element may involve transferring low density liquid from '2' to '3'.
Land	'Land' may comprise a solid structure or surface or earth which '1' and / or '3' are situated in Figure 31. The weight of '1' and / or '3' may be supported by said land in Figure 31.

Water	'Water' may comprise the body of liquid in which reservoir '2' is submerged.
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[0236]

Figure 32	
Diagram Element	Description
1	'1' or the first storage reservoir, may comprise a tank or reservoir storing a relatively low density liquid at a lesser hydrostatic pressure than the second storage region, '2'. '1' may exist at a pressure at or near the ambient pressure surrounding '1'. Alternatively, or additionally, '1' may exist at a pressure greater than ambient pressure surrounding '1', however less than the hydrostatic pressure of the second storage reservoir ('2'). Alternatively, or additionally, '1' may exist at a pressure less than ambient pressure surrounding '1', which may be less than the hydrostatic pressure of the second storage reservoir ('2'). In Figure 32, the process may be undergoing 'charging'. During charging, low density liquid may be pumped from '1' to '2', using pump '3'. '2' may be located beneath the surface of a body of liquid with greater density than the low density liquid and/or may exist at a greater hydrostatic pressure than '1'. If '1' comprises a contractable or collapsible tank, the total volume occupied by the tank or total volume of liquid in the tank may decrease during 'charging'.
2	'2' or the second storage reservoir may comprise a tank or reservoir storing a relatively low density liquid at a greater hydrostatic pressure than the first storage region, '1'. '2' may exist at a pressure at or near the ambient pressure surrounding '2'. Alternatively, or additionally, '2' may exist at a pressure greater than ambient pressure surrounding '2' and / or greater than the hydrostatic pressure of the '1'. Alternatively, or additionally, '2' may exist at a pressure less than ambient pressure surrounding '2', which may be greater than the hydrostatic pressure of '1'. In Figure 32, the process may be undergoing 'charging'. During charging, low density liquid may be pumped from '1' to '2', using pump '3'. '2' may be located beneath the surface of a body of liquid with greater density than the low density liquid and/or may exist at a greater hydrostatic pressure than '1'. If '2' comprises a contractable or collapsible tank, the total volume occupied by the tank or total volume of liquid in the tank may increase during 'charging'.
3	'3' may comprise a pump and / or generator and / or valve. '3' may be employed to generate power from low density liquid transferred from '2' to '1' during discharging. '3' may be employed to pump low density liquid from '1' to '2' during charging. '3' may comprise a pump, which may be reversibly employed as a generator. '3' may comprise a pump separate from a generator. '3' may comprise multiple pumps and generators or reversible pump/generators. '3' may act as a valve which separates

	relatively high pressure low density liquid in the pipe 'Line/Arrow Between '2' and '3'' from the relatively low pressure low density liquid in the pipe 'Line/Arrow Between '1' and '3''. In Figure 32, '3' may be pumping low density liquid from '1' to '2', which may comprise charging the energy storage device.
Electricity	'Electricity' may comprise a source of electricity or an application requiring electricity or both. 'Electricity' may encompass transmission equipment and / or electricity grid infrastructure and / or applications generating or using electricity. In Figure 32, 'Electricity' may comprise electricity consumed by '3' (and stored by the energy storage device) during charging. In Figure 32, electricity may be transferred using undersea cables or using underground cables or using subsea cables or using light, or using microwaves, or by oxidation of a fuel, or by reversible consumption of a fuel, or by discharging a transportable battery.
Line/Arrow Between '1' and '3'	The present diagram element may comprise a means for transferring low density liquid from '1' to '3'. For example, the present diagram element may comprise a pipe or set of pipes. Said pipe may be compatible with the low density liquid.
Line/Arrow Between '3' and '2'	The present diagram element may comprise a means for transferring low density liquid from '3' to '2'. For example, the present diagram element may comprise a pipe or pipes. The present diagram element may involve a pipe which experiences a pressure difference between internal liquid contents and liquid surrounding the pipe. Said pressure difference may vary depending on the depth of the section of pipe beneath the surface of the water body, the depth of reservoir '2' compared to reservoir '1' or to '3', the hydrostatic pressure difference between reservoir '1' and reservoir '2', and/or the density of the low density liquid and/or the density of the liquid surrounding the section of pipe. In Figure 32, the present diagram element may involve transferring low density liquid from '3' to '2'.
Water	'Water' may comprise the body of liquid which '1', '2', and / or '3' are situated and / or submerged in Figure 32.

[0237]

Figure 33	
Diagram Element	Description
1	'1' or the first storage reservoir, may comprise a tank or reservoir storing a relatively low density liquid at a lesser hydrostatic pressure than the second storage region, '2'. '1' may exist at a pressure at or near the ambient pressure surrounding '1'. Alternatively, or additionally, '1' may exist at a pressure greater than ambient pressure surrounding '1', however less than the hydrostatic pressure of the second storage reservoir ('2'). Alternatively, or additionally, '1' may exist at a pressure less than ambient pressure surrounding '1', which may be less than the hydrostatic pressure of the second storage reservoir ('2'). In Figure

	33, the process may be undergoing 'discharging'. During discharging, low density liquid may be released from '2' to '1', generating electricity by powering generator '3'. '2' may be located beneath the surface of a body of liquid with greater density than the low density liquid and/or may exist at a greater hydrostatic pressure than '1'. If '1' comprises a contractable or collapsible tank, the total volume occupied by the tank or total volume of liquid in the tank may increase during 'discharging'.
2	'2' or the second storage reservoir may comprise a tank or reservoir storing a relatively low density liquid at a greater hydrostatic pressure than the first storage region, '1'. '2' may exist at a pressure at or near the ambient pressure surrounding '2'. Alternatively, or additionally, '2' may exist at a pressure greater than ambient pressure surrounding '2' and / or greater than the hydrostatic pressure of the '1'. Alternatively, or additionally, '2' may exist at a pressure less than ambient pressure surrounding '2', which may be greater than the hydrostatic pressure of '1'. In Figure 33, the process may be undergoing 'discharging'. During discharging, low density liquid may be released from '2' to '1', generating electricity by powering generator '3'. '2' may be located beneath the surface of a body of liquid with greater density than the low density liquid and/or may exist at a greater hydrostatic pressure than '1'. If '2' comprises a contractable or collapsible tank, the total volume occupied by the tank or total volume of liquid in the tank may decrease during 'discharging'.
3	'3' may comprise a pump and / or generator and / or valve. '3' may be employed to generate power from low density liquid transferred from '2' to '1' during discharging. '3' may be employed to pump low density liquid from '1' to '2' during charging. '3' may comprise a pump, which may be reversibly employed as a generator. '3' may comprise a pump separate from a generator. '3' may comprise multiple pumps and generators or reversible pump/generators. '3' may act as a valve which separates relatively high pressure low density liquid in the pipe 'Line/Arrow Between '2' and '3'' from the relatively low pressure low density liquid in the pipe 'Line/Arrow Between '1' and '3''. In Figure 33, '3' may be generating power from the release of low density liquid from '2' to '1', which may comprise discharging the energy storage device.
Electricity	'Electricity' may comprise a source of electricity or an application requiring electricity or both. 'Electricity' may encompass transmission equipment and / or electricity grid infrastructure and / or applications generating or using electricity. In Figure 33, 'Electricity' may comprise electricity generated by '3' during discharging and / or the transmission and / or utilization of said electricity. In Figure 33, electricity may be transferred using undersea cables or using underground cables or using subsea cables or using light, or using microwaves, or by conversion into a fuel, or by reversible production of a fuels, or by charging a transportable

	battery, or may be used by a nearby application, or may be used by an application on land, or may be used by an application on the body of water, or a combination thereof.
Line/Arrow Between '1' and '3'	The present diagram element may comprise a means for transferring low density liquid from '3' to '1'. For example, the present diagram element may comprise a pipe or set of pipes. Said pipe may be compatible with the low density liquid.
Line/Arrow Between '3' and '2'	The present diagram element may comprise a means for transferring low density liquid from '2' to '3'. For example, the present diagram element may comprise a pipe or pipes. The present diagram element may involve a pipe which experiences a pressure difference between internal liquid contents and liquid surrounding the pipe. Said pressure difference may vary depending on the depth of the section of pipe beneath the surface of the water body, the depth of reservoir '2' compared to reservoir '1' or to '3', the hydrostatic pressure difference between reservoir '1' and reservoir '2', and/or the density of the low density liquid and/or the density of the liquid surrounding the section of pipe. In Figure 33, the present diagram element may involve transferring low density liquid from '2' to '3'.
Water	'Water' may comprise the body of liquid which '1', '2', and / or '3' are situated and / or submerged in Figure 33.

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[0238] Example Step-by-Step Description

[0239] Charging: Low density liquid is pumped from reservoir '1' to reservoir '2' using pump '3'. Power is stored in the gravitational potential energy and/or hydrostatic pressure difference of the low density liquid stored at reservoir '2' relative to reservoir '1'.

[0240] Discharging: Low density liquid is released from reservoir '2' and transferred to reservoir '1', generating electricity using generator '3'. Power is generated by releasing energy stored in the gravitational potential energy and / or hydrostatic pressure difference of the low density liquid stored at reservoir '2' relative to reservoir '1'.

[0241] Example Calculations

[0242] The below table shows key metrics on the energy density and cost of the butane in the present gravitational potential energy storage device. Cost figures employ an example butane commodity price of \$0.60 USD per gallon.

[0243]

Difference in Ocean Water Depth between Reservoir 1 and 2 (m)	Wh per liter of Butane	kWh per m ³ of Butane	Tons of Butane per kWh	Tons of Butane per MWh	Tons of Butane per GWh	Cost of Butane per kWh (USD)
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100	125.7667	0.125766667	4.556056	4556.056	4556056	722.15
200	251.5333	0.251533333	2.278028	2278.028	2278028	361.075
300	377.3	0.3773	1.518685	1518.685	1518685	240.7167
400	503.0667	0.503066667	1.139014	1139.014	1139014	180.5375
500	628.8333	0.628833333	0.911211	911.2112	911211.2	144.43
600	754.6	0.7546	0.759343	759.3427	759342.7	120.3583
700	880.3667	0.880366667	0.650865	650.8652	650865.2	103.1643
800	1006.133	1.006133333	0.569507	569.507	569507	90.26875
900	1131.9	1.1319	0.506228	506.2285	506228.5	80.23889
1000	1257.667	1.257666667	0.455606	455.6056	455605.6	72.215
1500	1886.5	1.8865	0.303737	303.7371	303737.1	48.14333
2000	2515.333	2.515333333	0.227803	227.8028	227802.8	36.1075
2500	3144.167	3.144166667	0.182242	182.2422	182242.2	28.886
3000	3773	3.773	0.151869	151.8685	151868.5	24.07167
3500	4401.833	4.401833333	0.130173	130.173	130173	20.63286
4000	5030.667	5.030666667	0.113901	113.9014	113901.4	18.05375
4500	5659.5	5.6595	0.101246	101.2457	101245.7	16.04778
5000	6288.333	6.288333333	0.091121	91.12112	91121.12	14.443

[0244] Notes

[0245] Note: Electricity may be transferred from or to an electricity grid or application requiring or supply electricity.

[0246] Note: Electricity may be transferred using, for example, undersea or underground or above ground or a combination thereof power lines.

[0247] Note: The lines / arrows between '1' and '3' and '3' and '2' may represent the transfer of low density liquid between these process elements. Liquid may be transferred using, for example, pipes or transport vehicles. If liquid is transferred using pipes, it may be desirable for said pipe to be, including, but not limited to, one or more or a combination of the following: located on the surface of the ground, or suspended above the surface of the ground, or located beneath the ground, or comprise a subsurface pipeline, or comprise an underground pipeline, or comprise a pipeline beneath water and above ground, or comprise a pipeline beneath ground and beneath water, or comprise a pipeline above water and above ground.

[0248] Note: Expandable or collapsible reservoir may comprise a liquid storage vessel which can expand or contract in volume to allow for the storage of more or less liquid, respectively. The pressure inside said reservoir may be close to or equal to the pressure surround said reservoir. Said reservoirs may include, but is not limited to, expandable or collapsible liquid storage devices, which may include, but are not limited to, one or more or a combination of the following: pillow

tanks, or onion tanks, or balloon tanks, or bag tanks, fabric tanks, or bladder tanks, or folding tanks, or flexible tanks, or bellows tanks, or accordion tanks, or liner tanks.

[0249] Note: The present invention may comprise a LPG storage facility, or an oil storage facility, or a strategic LPG reserve, or a strategic oil reserve.

[0250] Note: The present invention may be employed to store a fuel or commodity chemical, while simultaneously employing said fuel or other commodity chemical as an gravitational electricity storage medium. This may enable the owner or operator of the facility to have an additional source of revenue (the storage or release of electricity), in addition to revenue from the storage of the fuel or other commodity chemical. By employing the present invention as a storage facility, instead of purchasing or leasing the low density liquid, the facility owner may be paid storage fees to store the low density liquid, which may further improve economics of the facility. A proportion of the low density liquid storage in the facility may be available for ‘commodity storage’ while a proportion of the low density liquid storage in the facility may be intended for permanent or semi-permanent storage. The proportion of low density liquid storage available for ‘commodity storage’ relative to the proportion of low density liquid storage intended to be permanently or semi-permanently in the facility may vary by facility and may be dependent on multiple economic factors and the priorities of the facility.

[0251] Note: ‘Commodity storage’ may comprise flexible or semi-flexible storage may comprise a portion of the storage facility’s low density liquid in storage which may be removed or added on a regular basis for market needs, such as commodity traders or other entities involved with the commodity market. If desired, the proportional low density liquid storage capacity devoted to ‘commodity storage’ may comprise the proportion of low density liquid which can be added or removed without substantially impacting the performance or capacity or capabilities of the electricity storage. The threshold of said ‘substantially impacting’ may vary by facility based on economic factors and facility priorities. ‘Semi-permanent storage’ may comprise long term storage or storage which may be utilized in periodic or very rare instances. For example, applications for semi-permanent storage may include, but are not limited to, storage for a commodity asset backed fund, storage for a commodity asset backed ETF or ETN, or storage for a strategic reserve. Permanent storage may involve low density liquid which is intended to remain in the facility and / or may be necessary for the proper operation of the facility.

[0252] Note: Stored low density liquid may be employed as a stored asset or physical asset backing a commodity tracking ETF or other fund. The low density liquid storage facility owner or operator may generate revenue from the electricity markets as an energy storage service, as well

as generate revenue from the management fees generated by the ETF for storing the low density liquid backing the ETF. The ability to have these two revenue streams may enable the facility owner or operator to generate more revenue from the facility, or may enable lower CAPEX of the facility, or may enable lower management fees for the ETF, or a combination thereof. To ensure the assets backing the ETF or ETN are sufficiently readily available or transferrable, a portion of the low density liquid may be always stored in storage reservoir '1' to satisfy short term needs of low density liquid.

[0253] Note: The temperature of water in the ocean beneath a certain depth may be relatively stable. Liquid in storage reservoir '2' be cooled or heated by the surrounding ocean water temperatures, depending on the ambient temperature conditions surrounding reservoir '1' and the ambient conditions surrounding reservoir '2'. For example, the ambient conditions surround reservoir '2' may be colder than the ambient conditions surrounding reservoir '1'. In said example, the relatively cool temperatures of liquid transferred from reservoir '2' to reservoir '1' may be harnessed to supply cooling to one or more applications requiring cooling. An example application requiring cooling may be the pump or generator '3'. For example, the ambient conditions surround reservoir '2' may be warmer than the ambient conditions surrounding reservoir '1'. In said example, the relatively warm temperatures of liquid transferred from reservoir '2' to reservoir '1' may be harnessed to supply heating or enthalpy to one or more applications requiring heating or enthalpy. Said certain depth may comprise less than, greater than or equal to, one or more or a combination of the following: 300 meters, or 400 meters, or 500 meters, or 600 meters, or 700 meters, or 800 meters, or 900 meters, or 1,000 meters, or 1,100 meters, or 1,200 meters, or 1,300 meters, or 1,400 meters, or 1,500 meters, or 1,750 meters, or 2,000 meters.

[0254] Note: Due to the low density liquid being a liquid and liquids being essentially incompressible compared to gases, the round trip efficiency of the present pressure and/or gravitational energy storage device may possess a significantly greater round trip efficiency relative to energy storage devices which employ pressurized gases. For example, the round trip efficiency of the present invention may be greater than or equal to 40%, or 50%, or 60%, or 70%, or 75%, or 80%, or 85%, or 90% or 95%.

[0255] Note: The low density liquid may possess a low viscosity, for example, a viscosity near, equal to, or less than water. For example, butane possesses a dynamic viscosity of ~0.2 cP at 1°C, compared to a dynamic viscosity of 1.73 cP at 1°C for water. Other low density liquids other than or in addition to butane may possess a lesser viscosity than water. Low viscosity may be advantageous, for example, because lower viscosity liquids may enable smaller pipe diameter,

lower CAPEX, lower pumping energy losses, greater round-trip efficiency, and greater distances between reservoir '1' and reservoir '2'.

[0256] Note: Compatibility with low density liquid, compatibility with water or ocean water, biofouling, compatibility with pressure. For pipes transferring low density liquid, the pressure difference between the low density liquid inside the pipe and the water surrounding the pipe increases with decreasing depth beneath the surface of the water. To, for example, minimize CAPEX, the pressure rating of the pipe may increase with greater pressure difference. For example, pipe near reservoir '2' may possess lower pressure rating (and/or may be lower cost) and pipe near reservoir '1' may possess greater pressure rating (and/or may be greater cost).

[0257] Note: Reservoir '2' and / or reservoir '1' may be anchored or connected or fixed or tethered to the land on the bottom of the body of liquid (e.g. body of water).

[0258] Note: Storage reservoirs or tanks may include, but are not limited to, one or more or a combination of the following: a pillow tank, or an onion tank, or a balloon tank, or a bag tank, or a fabric tank, or a bladder tank, or a folding tank, or a flexible tank, or a bellows tank, or an accordion tank, or a liner tank, or a rigid tank, or a piston tank, or an actuator tank, or a valve tank, or a basin tank, or a cement tank, or a wood tank, or a plastic tank, or a ceramic tank, or a fiber tank, or a composite tank, or a rubber tank, or a flexible tank.

[0259] Note: Pipe materials may include, but are not limited to, one or more or a combination of the following: plastic pipes, composite pipes, metallic pipes, fiber pipes, resin pipes, wood pipes, cement pipes, flexible pipes, rubber pipes, rigid pipes.

[0260] Note: It may be desirable to attach the first and / or second reservoirs to higher density materials to reduce the buoyance of the reservoirs. In the case of the first reservoir, the distance between the reservoir and land at the bottom of a water body be substantial enough to justify the attachment of higher density materials to the first reservoir to reduce the cost of tethering cables. Tethering cables may be employed to counteract the buoyancy of a reservoir and / or to ensure the reservoir is in an appropriate location relative to the other reservoir(s). In some embodiments, the distance between the first reservoir and land at the bottom of a water body may be sufficiently substantial the attachment of higher density materials to the first reservoir costs less than the cost reduction in the of tethering cables.

[0261] Note: In some embodiments, the location of the first reservoir may be maintained using a dynamic positioning system. A dynamic positioning system may employ various sensors, or GPS, or radar, or other positioning instruments to inform an operating system of changes in the current position and / or changes in position of the first reservoir and / or external thrust vectors,

such as currents. If the position changes of the first reservoir changes and / or if a thrust vector is detected, aquatic or marine engines may be employed to counteract said external thrust vectors and / or changes in position to ensure the first reservoir maintains a desirable position. If desirable, the higher density material attachments to the first reservoir may make the first reservoir at a similar density or neutral density relative to the surrounding water body. If desirably the first reservoir may employ mechanisms to dynamically adjust its density, using, for example, the addition of higher density material, the addition of lower density material (for example: low density liquid or a gas, such as air), the release of higher density material, or the release of lower density material). Said mechanism(s) to dynamically adjust density may also be incorporated within a dynamic positioning system. A dynamic positioning system may also be employed in the second reservoir.

[0262] Note: Collapsible or contractable may involve a structure or vessel or tank which can decrease in occupied volume or storage capacity reversibly.

[0263] Note: Expandable may involve a structure or vessel or tank which can increase in occupied volume or storage capacity reversibly.

[0264] Note: Lower density liquid may be soluble or partially soluble in the higher density liquid. Advantageously, the lower density liquid may be separate from the higher density liquid with a physical barrier, which may prevent the dissolution of lower density liquid in higher density liquid. For example, said physical barrier may involve a storage tank liner or walls or pipes or a combination thereof.

[0265] Note: In some instances, low density liquids or liquids with a density less than water may have a boiling point near or less than the outside air or water temperature and / or may possess a large vapor pressure at the temperature of the outside air or water. In said instances, it may be desirable for the first reservoir to be a pressurized or rigid tank. For example, a pressurized or rigid storage tank may enable low density liquid to remain at a liquid phase while being at a temperature above the low density liquid's atmospheric pressure boiling point. In said instances wherein a rigid or pressurized tank is employed at the first storage reservoir, when liquid, such as low density liquid, is removed from the first storage reservoir, the total volume of the rigid or pressurized tank may remain the same. A volume in the tank formerly occupied by liquid phase low density liquid may instead be occupied by gas phase low density liquid. Said gas phase low density liquid may exist in the head space above liquid phase inside the tank, such as liquid phase low density liquid. When liquid, such as low density liquid, is added to the first storage reservoir, the total volume of the rigid or pressurized tank may remain the same. A volume in the tank

formerly occupied by gas phase low density liquid may instead be occupied by liquid phase low density liquid. Example low density liquids which may be applicable may include, but not limited to, Liquefied Petroleum Gas (LPG), or propane, or butane, or diethyl ether, or dimethyl ether, or methoxypropane, or methanol, or acetone, or pentane, or hexane, or petroleum ether, or methoxyethane, or liquid natural gas (LNG), or gasoline, or Diisopropyl ether, or alkanes, or alkenes, or alkynes, or cycloalkanes, or a combination thereof.

- **Note:** The present invention may employ devices for leak detection and / or leak prevention. Additionally, the present invention may employ methods to minimize losses or damage caused by a leak. For example, a containment mechanism, such as, for example, including but not limited to, a liner, or blanket, or tarp, or fabric, or funnel, or float, or other containment mechanism, or a combination thereof, may be placed above or suspended above the second reservoir and / or pipes and / or pipe connections. In the event of a leak, low density liquid may rise from the leak and may be captured or caught by said containment mechanism. Said containment mechanism may be effective because low density liquid may tend to float and said containment mechanism may cover a portion or the entire surface area of the second reservoir and / or pipes and / or pipe connections above said second reservoir and / or pipes and / or pipe connections. Low density liquid captured by said containment mechanism may be, if desirable, funneled within said containment mechanism and, if desirable, may be transferred to the surface using a return pipe, where the low density liquid may be recovered. The contact of low density liquid with a portion of the containment vessel or pipe may trigger a sensor or sensors which alert system operators of the need to fix a leak. For example, the said sensor may involve a mechanism for measuring the increased buoyancy of the containment mechanism due to the capturing or containment of leaked low density liquid. For example, said sensor may involve a mechanism for measuring the flow rate of liquid in said return pipe, wherein the presence of at least a certain liquid flow rate may indicate the presence of a low density liquid leak. For example, said sensor may involve a mechanism for detecting low density liquid using spectroscopy or measurements of density or molecular weight or a combination thereof. For example, said sensor may involve measuring the change in mass or pressure or volume in a container connected to said return pipe. For example, said sensor

may involve measuring changes in mass or capacity in the first or second reservoir, which may include changes in said mass or energy storage capacity when the process is at a steady state or unexplained changes in mass or energy storage capacity. A first reservoir may employ said containment mechanisms and / or sensors. For example, a first reservoir and / or pump and / or generator may employ said containment mechanisms and / or sensors if, for example, a first reservoir and / or pump and / or generator is located beneath the surface of a water body.

- **Note:** Low density liquid or pipes or vessels or reservoirs or a combination thereof may contain a medium which reacts in the event of or at the site of a leak. For example, a material in the walls of a pipe or vessel or reservoir may react with low density liquid if low density liquid begins to leak. Said reaction may inhibit or block or prevent a leak. Said reaction may involve, including, but not limited to one or more or a combination of the following: an absorption reaction, or a swelling reaction, or a foaming reaction, or an expansion reaction, a reaction to form a solid, a reaction to form a viscous liquid, or a combination thereof. Alternatively, or additionally, the low density liquid or walls of pipes or vessels or reservoirs or a combination thereof may contain a reagent which reacts with water or air or salt in water upon exposure to water or air. Said reaction may inhibit or block or prevent a leak. Said reaction may involve, including, but not limited to one or more or a combination of the following: an absorption reaction, or a swelling reaction, or a foaming reaction, or an expansion reaction, a reaction to form a solid, a reaction to form a viscous liquid, or a combination thereof. Said reaction may involve forming a material which is more easily or readily captured, or a material which is more environmentally friendly, or a material which may inhibit further leakage, or a material which may simplify or facilitate the process of leakage detection, or a material which may reduce the cost or damage associated with a leakage. For example, said reaction may involve forming a liquid of a certain color or said reaction may involve a tracing reagent.
- **Note:** Low density liquid or pipes or vessels or reservoir or a combination thereof may contain a tracing chemical or reagent which may facilitate leak detection. For example, parts or components of pipes or vessels or reservoir may contain a material, which, when exposed to water, or salt water, or low density liquid, or

air, or a combination thereof, may change one or more properties to facilitate detection of leaks or wear or other forms of damage or exposure. For example, said properties may include, but are not limited to, color, electrical conductivity, electrical resistivity, thermal conductivity, surface texture, surface morphology, absorbance spectra, vibration frequency, flexibility, temperature, density, rigidity, or a combination thereof.

- **Note:** The temperature beneath a water body and the temperature above a water body may be different. Additionally, water bodies themselves may possess a range of different temperatures, which may correlate with depth. The temperature of a water body relative to its depth may be known as a water body thermocline. In ultra-deep water bodies, such as an ocean or lake, the temperature of a water body below about 1000 meters or about 1250 meters or about 1500 meters ranges from about 3 to 8°C because water is generally most dense at about 4°C. For example, in the ocean, the temperature of the water below 1500 meters is generally near 4°C, even if the temperature of the water at the ocean surface is warm, such as, for example, greater than 15°C or greater than 20°C. In the present invention, the second reservoir may be located at a different depth than the first reservoir. The temperature of the water surrounding the second reservoir may be relatively constant or stable, if, for example, the second reservoir is located at a depth beneath a water body of greater than 100 meters, or 200 meters, or 300 meters, or 500 meters, or 700 meters, or 900 meters, or 1000 meters, or 1250 meters, or 1500 meters. The temperature of the air or water adjacent to or surrounding the first reservoir may be different from the temperature of the water surrounding the second reservoir. The temperature difference between the second reservoir and the first reservoir may be beneficially utilized or harnessed. For example, if the temperature of the second reservoir is less than the first reservoir or the temperature of things adjacent to the first reservoir, power may be generated from the difference in temperature between liquid returning from the second reservoir and the surrounding ambient temperature near the first reservoir or the temperature inside the first reservoir or another heat source or thermal source or enthalpy source. For example, if the temperature of the second reservoir is greater than the first reservoir or the temperature of things adjacent to the first reservoir, power may be generated from the difference in temperature

between liquid returning from the second reservoir and the surrounding ambient temperature near the first reservoir or the temperature inside the first reservoir or another cold source or heat sink or enthalpy sink. For example, if the temperature of the second reservoir is less than the first reservoir or the temperature of things adjacent to the first reservoir, liquid from the second reservoir may be employed as a cooling medium or cooling source or for district cooling to provide valuable or useful cooling to one or more applications requiring cooling. For example, if the temperature of the second reservoir is greater than the first reservoir or the temperature of things adjacent to the first reservoir, liquid from the second reservoir may be employed as a heating medium or heat source or for district heating to provide valuable or useful heating to one or more applications requiring heating. For example, if the temperature of the second reservoir is less than the first reservoir or the temperature of things adjacent to the first reservoir, liquid from the second reservoir may be employed as a cooling source to power or facilitate a desalination process or a process for removing water from gas streams or air. For example, if the temperature of the second reservoir is less than the first reservoir or the temperature of things adjacent to the first reservoir, it may be desirable to insulate said first reservoir or one or more pipes. Said insulation may enable the first reservoir to remain at a cooler temperature, which may be advantageous, for example, if the low density liquid has a low boiling point or is volatile and minimizing temperature in the first reservoir minimizes pressure in the first reservoir. Said insulation may also prevent the formation of condensation on a tank.

- **Note:** The present invention may also be employed as a means for ocean thermal energy conversion (OTEC).
- **Note:** If desirable, one or more components of the present invention may be heated or cooled or temperature controlled or a combination thereof.
- **Note:** Low density liquid may possess a freezing point less than water, which may be advantageously utilized. For example, the first reservoir may be employed as a cold or thermal storage unit, for, for example, providing cooling for a refrigerated or frozen storage facility. Said cold storage may be employed, for example, to optimize energy consumption or for grid load shifting or load curtailment. For example, the first reservoir may be employed as a cryogenic

cold storage or thermal storage unit. Alternatively or additionally, cool low density liquid may be employed as a low temperature heat transfer fluid and / or as a low temperature thermal storage medium. For example, low density liquid may be employed in applications which require cooling, which may include, but are not limited to, one or more or a combination of the following: district cooling, or cooling for a desalination facility, or cooling for a power plant, or cooling for an air separation unit, or cooling for a liquification facility, or cooling for a HVAC system. For example, LNG gasification facilities may produce significant waste cooling. LNG gasification facilities may employ low density liquid in or from said first reservoir as a heat source or enthalpy source, cooling said low density liquid in the process. Due to its potentially lower freezing point, low density liquid may be cooled to a lower temperature than water while remaining at a liquid phase, enabling heat transfer or large scale thermal storage or both at temperatures near, at, or below the freezing point of water. Additionally, because the first reservoir is interconnected to the second reservoir and the second reservoir may be located at a relatively consistent 'cold' temperature, 'warm' low density liquid may be near 4°C or otherwise below ambient temperature. Advantageously, because 'warm' low density liquid may be significantly less than ambient temperatures, more energy may be recovered from 'cold sources' than if said low density liquid was near or at ambient temperatures.

- **Note:** Low density liquid or high density liquid or both may be employed as a heat transfer fluid, or as a thermal storage fluid, or may be employed in ocean thermal energy conversion.

[0266] Example Exemplary Embodiments:

[0267]

1. A system for storing or generating electricity comprising:
a first storage reservoir configured to be near the surface of a body of water and configured to store a fluid which has a lower density than water;
a second storage reservoir configured to be located below the surface of the body of water;
a pump; and
a generator;
wherein the pump, generator, and the first and second reservoir are operatively connected such that electricity is stored by displacing water adjacent the second storage reservoir by pumping low

density fluid in the first storage reservoir to the second storage reservoir and electricity is generated or discharged by allowing the low density fluid in the second storage reservoir to return to the first storage reservoir; and,

wherein the water and the fluid which has a lower density than water are both in liquid form.

2. The system of Embodiment 1 wherein said second storage reservoir is expandable, contractible, or collapsible.

3. The system of Embodiment 1 wherein said second storage reservoir is a pillow tank, an onion tank, a balloon tank, a bag tank, a fabric tank, a bladder tank, a folding tank, a flexible tank, a bellows tank, an accordion tank, or a liner tank.

4. The system of Embodiment 1 wherein said second storage reservoir comprises a concave region with an opening near the bottom of said concave region wherein said opening is open to the body of water.

5. A system for storing or generating electricity comprising:

a first storage reservoir configured to store a fluid which has a lower density than water;

a second storage reservoir configured to be located below a surface of a body of water wherein the second storage reservoir is at a greater depth beneath the surface of a water body than the first storage reservoir;

a pump; and

a generator;

wherein the pump, generator, and the first and second reservoir are operatively connected such that

(1) electricity is stored by pumping low density fluid in the first storage reservoir to the second storage reservoir to displace water; or

(2) electricity is generated or discharged by allowing low density fluid in the second storage reservoir to return to the first storage reservoir; or

(3) both (1) and (2);

wherein the water and the fluid which has a lower density than water are both in liquid form.

6. The system of Embodiment 5 wherein the displaced water is in the second storage reservoir.

7. The system of Embodiment 5 wherein the displaced water is water within the body of water and wherein the displaced water is adjacent the second storage reservoir.

8. The system of Embodiment 5 wherein the water pump and the generator are the same unit.

9. The system of Embodiment 5 wherein said first storage reservoir, said second storage reservoir, or both comprise an expandable or contractible or collapsible structure.
10. The system of Embodiment 5 wherein said first storage reservoir, said second storage reservoir, or both comprise a pillow tank, an onion tank, a balloon tank, a bag tank, a fabric tank, a bladder tank, a folding tank, a flexible tank, a bellows tank, an accordion tank, or a liner tank.
11. The system of Embodiment 5 wherein said second storage reservoir comprises a concave region with an opening near the bottom of said concave region open to the body of water.
12. The system of Embodiment 5 wherein said second storage reservoir is tethered to the bottom of said water body.
13. The system of Embodiment 5 wherein the fluid having a lower density than water comprises a hydrocarbon liquid.
14. The system of Embodiment 5 which further comprises a dynamic positioning system to maintain or adjust a position of the first reservoir, the second reservoir or both.
15. The system of Embodiment 5 further comprising an operative connection to an electricity grid or electricity transmission infrastructure.
16. The system of Embodiment 5 wherein said second storage reservoir is configured to store a fluid which has a lower density than water.
17. The system of Embodiment 5 wherein said first and second reservoirs are connected by one or more pipes.
18. The system of Embodiment 5 wherein said pump and generator comprise a single unit.
19. The system of Embodiment 5 wherein said first reservoir is configured to be located beneath the surface of a water body.
20. The system of Embodiment 5 wherein the fluid having a lower density than water comprises propane, butane, LPG, pentane, hexane, or a mixture thereof.
21. The system of Embodiment 5 wherein the fluid having a lower density than water comprises an alcohol, an ether, an ester, or a mixture thereof.
22. The system of Embodiment 5 wherein the fluid having a lower density than water comprises methanol, ethanol, propanol, acetone, dimethyl ether, diethyl ether, or a mixture thereof.
23. The system of Embodiment 9 wherein said second reservoir is configured to collapse or contract during discharge.
24. The system of Embodiment 26 wherein said collapsing or contracting is due to water adjacent said second reservoir displacing the fluid having a lower density than water.
25. The system of Embodiment 9 wherein said second reservoir expands during charging.

26. The system of Embodiment 25 wherein said expanding is due to the fluid having a lower density than water entering the second reservoir and displacing water adjacent said second reservoir.
27. The system of Embodiment 19 wherein said first reservoir is configured to be tethered to a bottom of the water body.
28. The system of Embodiment 19 wherein said first reservoir is configured to be attached to a material with a greater density than water to reduce buoyancy.
29. The system of Embodiment 19 wherein said first reservoir is configured to be attached to a material with a greater density than water, be neutrally buoyant, and wherein the first reservoir is configured such that its position is maintained or adjusted with a dynamic positioning system.
30. The system of Embodiment 5 wherein said second reservoir is attached to a material with a greater density than water to reduce buoyancy.

Summary of Additional Embodiment Relating to Liquid Displacement

[0268] The present invention pertains to systems and methods for storing or generating electricity. Some embodiments pertain to systems or methods for the storage of energy by displacing a higher density liquid with a lower density liquid. Some embodiments relate to systems or methods for facilitating the storage or generation of electricity. Some embodiments relate to environmental, health, and safety mechanisms. Some embodiments related to systems and configurations to enable energy storage in particular geography types. Some embodiments related to systems and configurations to enable energy storage with low density liquid working fluids with various levels of volatility or vapor pressure. Some embodiments pertain to ensuring optimal energy storage performance.

Example Definitions:

- **Condensable Gas:** A chemical or mixture of chemicals which phase transitions from a liquid to a gas or a gas to a liquid or both reversibly or possesses a boiling point or a combination thereof at the following conditions:
 - Vapor pressures less than 2.5 atm, or less than 5 atm, or less than 10 atm, or less than 15 atm, or less than 20 atm
 - Vapor pressures greater than 0.1 atm, or greater than 0.2 atm, or greater than 0.3 atm, or greater than 0.4 atm, or greater than 0.5 atm, or greater than 0.6 atm, or greater than 0.7 atm, or greater than 0.8 atm, or greater than 0.9 atm, or greater than 1.0 atm
 - Temperature in the range of 230 Kelvin to 380 Kelvin

- **Partially Discharged or Partially Charged:** A state where the energy storage system contains stored energy, although the stored energy is less than the energy storage system's full capacity to store energy. For example, when a surface LDL storage tank contains an amount of LDL greater than its minimum capacity and less than its maximum capacity. For example, when an underwater LDL storage tank contains an amount of LDL greater than its minimum capacity and less than its maximum capacity.
- **Maximum Capacity:** Maximum capacity may comprise the maximum amount of HDL or water and / or the maximum amount of LDL or both which can be stored in a given storage tank or in a region of the energy storage device or in general. For example, the maximum capacity of LDL in a subsea tank may comprise the maximum amount of LDL which can be stored in a subsea tank before the LDL is at risk of or may enter or enters a pipeline designed for transferring water. For example, the maximum capacity of HDL in a subsea tank may comprise the maximum amount of water or HDL which can be stored in a subsea tank before the HDL is at risk of or may enter or enters a pipeline designed for transferring LDL. For example, the maximum capacity of LDL in a subsea tank may comprise the maximum amount of LDL which can be stored in a subsea tank before the LDL is at risk of or may enter or enters a surface HDL or water tank. For example, the maximum capacity of HDL in a subsea tank may comprise the maximum amount of water or HDL which can be stored in a subsea tank before the HDL is at risk of or may enter or enters a surface LDL tank.
- **Minimum Capacity:** Minimum capacity may comprise the minimum amount of HDL or water and / or the maximum amount of LDL or both which can be stored in a given storage tank or in a region of the energy storage device or in general. For example, the minimum capacity of a tank for LDL or HDL may comprise the tank containing no or very little LDL or HDL. For example, the minimum capacity of LDL in a subsea tank may comprise the minimum amount of LDL which can be stored in a subsea tank before the HDL is at risk of or may enter or enters a pipeline designed for transferring LDL. For example, the minimum capacity of HDL in a subsea tank may comprise the minimum amount of water or HDL which can be stored in a subsea tank before the LDL is at risk of or may enter or enters a pipeline designed for transferring HDL. For example, the minimum capacity of LDL in a subsea tank may comprise the minimum amount of LDL which can be stored in a subsea tank before the HDL is at risk of or may enter or enters a surface LDL tank. For example, the minimum capacity of HDL in a subsea tank may comprise the minimum

amount of water or HDL which can be stored in a subsea tank before the LDL is at risk of or may enter or enters a surface HDL or water tank. The minimum volume or amount of LDL in the floating underwater tank may comprise the minimum amount of LDL required to ensure the floating underwater tank is buoyant.

- **A Pump and a Generator or A pump; and a generator:** A pump and a generator may comprise a combined pump/generator unit, which may include, but is not limited to, a hydraulic power recovery turbine (HPRT). Alternatively, or additionally, some embodiments may employ a separate pump and a separate generator.
- **First Reservoir:** The first reservoir comprises one or more or a combination of tanks configured to store low density liquid and may be located at an elevation higher or greater than a second reservoir.
- **Second Reservoir:** The second reservoir comprises one or more or a combination of tanks configured to store low density liquid and may be located at an elevation lower or less than the first reservoir. The second reservoir may be configured to store both low density liquid and water. The second reservoir may be configured to store both low density liquid and water in a manner which low density liquid and water exchange volume or pressure, while preventing mixing or direct physical contact between the water and the low density liquid.
- **Third Reservoir:** The third reservoir may be interconnected to or comprise the ocean. The third reservoir may comprise a water tank or storage vessel. Said water tank or storage device may be on the surface, or above water, or underwater, or a combination thereof. An underwater water reservoir may comprise a tank or storage vessel or reservoir or water body comprising water interconnected to the second reservoir via a pipe. If desirable, at least a portion of the water tank or storage vessel third reservoir or water interconnected to the third reservoir may possess similar pressures or equilibrium pressure with the hydrostatic pressure of the ocean. If the density of the liquid inside the third reservoir is the same as ocean water, the third reservoir may be located at any elevation between the elevation of the first storage reservoir and the second storage reservoir or any elevation underwater.
- **Storage Vessel:** A storage vessel or tank may comprise a barrier to contain a material, such as a liquid, solid, or gas. A storage vessel or tank may comprise various configurations or materials, and may include, but is not limited to, storage tanks or vessels employed for storing liquid or multiphase media or a combination thereof known in the art.

- **Treated Ocean Water:** Treated ocean water may comprise water or aqueous solution origination from ocean water which is less corrosive than ocean water, or possesses a lower dissolved oxygen concentration than ocean water, or is less prone to the formation of biofouling or scaling than ocean water, or a combination thereof. It may be desirable for treated ocean water to possess a similar density to ocean water.
- **Tether:** A tether may comprise a cable or line or connector which connects a floating or buoyant structure with another structure. Said ‘another structure’ may comprise, including, but not limited to: the seafloor or a mooring or a vessel or another tank or an anchor, or a combination thereof.
- **Configured to Store a Fluid which has a Lower Density than Water and Water:** The present term may describe a reservoir or storage which is designed for the storage of water and a lower density liquid. The present term may include configuring storage which prevents water and lower density liquid from reacting, or dissolving, or forming a new phase. The present term may include configuring storage which ensures water and lower density liquid are physically separate while stored the same storage vessel.
- **Low Density Liquid:** A liquid with a lower density than a higher density liquid. A liquid with a lower density than the density of water. A liquid with a lower density than liquid water at a temperature greater than 3°C and / or less than 50°C.
- **Substantial Low Density Liquid – Water Hydrates:** “Substantial” may mean an amount or location or combination thereof of Low Density Liquid – Water Hydrates such that Low Density Liquid – Water Hydrates interferes with or disrupts the operation of the energy storage system.
- **Close to or About Equivalent to:** ‘Close to or About Equivalent to’ may represent a value which is within 10% of another value.
- **Sub-Tank:** A sub-tank may comprise a tank within or located on the inside of another tank or enclosed structure or concave structure or a combination thereof.
- **Rigid Containment Structure:** A rigid containment structure may comprise an enclosure or cover which holds a sub-tank or one or more other structures. A rigid containment structure may capture or recover low density liquid and / or debris in the event of a breach in a sub-tank or one or more other structures.
- **Mechanically Isolated:** An underwater tank mechanically isolated from ocean water surrounding or adjacent to it may involve a tank in which contents inside the tank operate under pressures isolated or independent from the pressure of the contents surrounding the

tank. A mechanically isolated tank may be a tank which does not exchange pressure with fluids or materials outside or surrounding the tank. For example, an underwater tank may possess a pressure inside the tank which is different from the pressure of the water surrounding the underwater tank – the shape and / or volume of the tank may remain unchanged. In some embodiments herein, the pressure inside an underwater tank may be close to or about equivalent to the hydrostatic pressure of water at the same depth as the tank, however the internal contents of the tank may not be exchanging pressure with the ocean water adjacent to or surrounding the tank. Achieving similar pressures inside a tank as outside a tank without exchanging pressure between the inside and outside of a tank may involve one or more or a combination of engineering systems and/or methods. For example, an engineered head space gas or condensable head space gas may be engineered to have a vapor pressure in the pressure range of the hydrostatic pressure of ocean water at the same depth as tank at a temperature in the range of the temperature inside the tank and / or the temperature of water surrounding or adjacent to said tank. By achieving similar pressures inside a tank as outside a tank without exchanging pressure between the inside and outside of a tank, an underwater tank or underwater rigid tank, for example, can be made from less material or less expensive materials or a combination thereof.

- **Breach:** A breach may comprise a break or leak or disconnection or accidental release which may result in the release of internal liquids, which may include, but is not limited to, low density liquid and / or water.

Detailed Figure Descriptions and Descriptions of Example Embodiments

[0269] **Figure 34:** The present figure may show an energy storage system which stores electricity by pumping a low density liquid from a tank at a higher elevation to a tank at a lower elevation, displacing water in the tank at a lower elevation. The present figure may show the present embodiment charging or storing electricity. The tank with low density liquid at a higher elevation may comprise a first reservoir. The tank with low density liquid and water at a lower elevation may comprise a second reservoir. The tank with water at a higher elevation may comprise a third reservoir or surface water tank. The density of water in the surface water tank may be close to or equal to the density of the ocean water. The pressure inside the second reservoir may be close to or about equivalent to the hydrostatic pressure of the ocean at the underwater depth of the second reservoir.

[0270] **Figure 35:** The present figure may comprise the same embodiment as Figure 34. The present figure may show the present embodiment at a nearly fully charged state.

[0271] **Figure 36:** The present figure may comprise the same embodiment as Figure 34. The present figure may show the present embodiment discharging or generating electricity.

[0272] **Figure 37:** The present figure may comprise the same embodiment as Figure 34. The present figure may show the present embodiment at a nearly fully discharged state.

[0273] **Figure 38:** Figure key for figures 34, 35, 36, and 37.

[0274] **Figure 39:** An energy storage system which stores electricity by pumping low density liquid from a first reservoir ("1") near the surface into an underwater second reservoir ("2"), displacing ocean water surrounding said second reservoir. The present figure shows the energy storage system charging by pumping low density liquid from the first reservoir to a second reservoir, displacing water surrounding the second reservoir. The first reservoir ("1") near the surface may be at an elevation greater than the elevation of the second reservoir ("2"). The first reservoir may be above water on land, or floating in the water, or underwater. In the present figure, the second reservoir is floating above the ocean floor. In the present figure, the second reservoir may be suspended above the ocean floor and may be buoyant. In the present figure, the second reservoir may be tethered to the ocean floor and / or anchored to the ocean bottom. In the present figure, the second reservoir may be surrounded by ocean water. The second reservoir may comprise a piston tank. The second reservoir may comprise an expandable or collapsible structure, such as an onion tank, or a bladder tank, or a pillow tank, or a storage bag. In the present figure, the internal pressure of the second reservoir may be close to or about equivalent to the hydrostatic pressure of water in contact with the bottom of the second reservoir.

[0275] **Figure 40:** An energy storage system which stores electricity by pumping low density liquid from a first reservoir ("1") near the surface into an underwater second reservoir ("2"), displacing ocean water surrounding said second reservoir. The present figure shows the energy storage system fully charged at a steady state. The first reservoir ("1") near the surface may be at an elevation greater than the elevation of the second reservoir ("2"). The first reservoir may be above water on land, or floating in the water, or underwater. In the present figure, the second reservoir is floating above the ocean floor. In the present figure, the second reservoir may be suspended above the ocean floor and may be buoyant. In the present figure, the second reservoir may be tethered to the ocean floor and / or anchored to the ocean bottom. In the present figure, the second reservoir may be surrounded by ocean water. The second reservoir may comprise a piston tank. The second reservoir may comprise an expandable or collapsible structure, such as an onion tank, or a bladder tank, or a pillow tank, or a storage bag. In the present figure, the

internal pressure of the second reservoir may be close to or about equivalent to the hydrostatic pressure of water in contact with the bottom of the second reservoir.

[0276] **Figure 41:** An energy storage system which stores electricity by pumping low density liquid from a first reservoir ("1") near the surface into an underwater second reservoir ("2"), displacing ocean water surrounding said second reservoir. The present figure shows the energy storage system discharging or generating electricity, wherein low density liquid inside the second reservoir is displaced by water surrounding the second reservoir ("2") and transferred through a pipe, through a generator, generating electricity, and into the first reservoir ("1"). The first reservoir ("1") near the surface may be at an elevation greater than the elevation of the second reservoir ("2"). The first reservoir may be above water on land, or floating in the water, or underwater. In the present figure, the second reservoir is floating above the ocean floor. In the present figure, the second reservoir may be suspended above the ocean floor and may be buoyant. In the present figure, the second reservoir may be tethered to the ocean floor and / or anchored to the ocean bottom. In the present figure, the second reservoir may be surrounded by ocean water. The second reservoir may comprise a piston tank. The second reservoir may comprise an expandable or collapsible structure, such as an onion tank, or a bladder tank, or a pillow tank, or a storage bag. In the present figure, the internal pressure of the second reservoir may be close to or about equivalent to the hydrostatic pressure of water in contact with the bottom of the second reservoir.

[0277] **Figure 42:** An energy storage system which stores electricity by pumping low density liquid from a first reservoir ("1") near the surface into an underwater second reservoir ("2"), displacing ocean water surrounding said second reservoir. The present figure shows the energy storage system at a fully discharged state. The first reservoir ("1") near the surface may be at an elevation greater than the elevation of the second reservoir ("2"). The first reservoir may be above water on land, or floating in the water, or underwater. In the present figure, the second reservoir is floating above the ocean floor. In the present figure, the second reservoir may be suspended above the ocean floor and may be buoyant. In the present figure, the second reservoir may be tethered to the ocean floor and / or anchored to the ocean bottom. In the present figure, the second reservoir may be surrounded by ocean water. The second reservoir may comprise a piston tank. The second reservoir may comprise an expandable or collapsible structure, such as an onion tank, or a bladder tank, or a pillow tank, or a storage bag. In the present figure, the internal pressure of the second reservoir may be close to or about equivalent to the hydrostatic pressure of water in contact with the bottom of the second reservoir.

[0278] **Figure 43:** Figure 43 is an energy storage system with tethers or anchors or tie down tethers labeled. “C” is labeling the tethers or anchors or tie downs. Said tethers or anchors or tie downs may be employed to connect an underwater tank (e.g. ‘2’) to the seafloor, which may enable an underwater tank (e.g. ‘2’) to be floating above the seafloor.

[0279] **Figure 44:** Figure 44 shows a water or HDL storage tank with a condensable gas in the headspace. The storage tank may be rigid in construction. “A” is labeling the yellow layer (light colored in black/white). “A” represents a practically insoluble condensed liquid comprising a condensable gas at a condensed (i.e. liquid) state. The said insoluble condensed liquid may comprise the same composition as the at least a portion of the gas in the headspace, “B”, and / or said insoluble condensed liquid vapor pressure may be at equilibrium or in equilibrium with the headspace gas. “B” represents the gases occupying the headspace. “A” contains less liquid in Figure 44 than Figure 45 because more condensable gas is at a condensed liquid state in Figure 45 compared to Figure 44. “6” may represent the third reservoir. A condensable headspace gas may enable the water tank to be drained of water while maintaining a relatively stable pressure inside said tank or without substantially reducing the pressure inside the water tank. A condensable headspace gas may enable the inside of an underwater rigid water tank to have an internal pressure close to the hydrostatic pressure of ocean water at the depth of the underwater rigid tank, while remaining mechanically isolated from the ocean water at the depth of the underwater rigid tank. A condensable headspace gas may have a vapor pressure or boiling point engineered to match a design pressure range within a design temperature range.

[0280] **Figure 45:** Figure 45 shows a water or HDL storage tank with a condensable gas in the headspace. The storage tank may be rigid in construction. “A” is labeling the yellow layer (light colored in black/white). “A” represents a practically insoluble condensed liquid comprising a condensable gas at a condensed (i.e. liquid) state. The said insoluble condensed liquid may comprise the same composition as the at least a portion of the gas in the headspace, “B”, and / or said insoluble condensed liquid vapor pressure may be at equilibrium or in equilibrium with the headspace gas. “B” represents the gases occupying the headspace. “A” contains more liquid in Figure 45 than Figure 44 because more condensable gas is at a condensed liquid state in Figure 45 compared to Figure 44, which may be due to water occupying a greater proportion of the volume in Figure 45. “6” may represent the third reservoir. A condensable headspace gas may enable the water tank to be drained of water while maintaining a relatively stable pressure inside said tank or without substantially reducing the pressure inside the water tank. A condensable headspace gas may enable the inside of an underwater rigid water tank to have an internal pressure close to the

hydrostatic pressure of ocean water at the depth of the underwater rigid tank, while remaining mechanically isolated from the ocean water at the depth of the underwater rigid tank. A condensable headspace gas may have a vapor pressure or boiling point engineered to match a design pressure range within a design temperature range.

[0281] **Figure 46:** An energy storage system which stores electricity by pumping low density liquid into a rigid underwater tank to displace water inside said rigid tank, wherein said water is displaced to an external underwater water reservoir. The present figure shows the present embodiment at a state of charging, for example, wherein electricity is powering a pump (“4”) to transfer low density liquid from a reservoir near the surface (“1”) to an underwater reservoir (“2”), for example, whereby low density liquid displaces water inside said underwater reservoir. The pressure inside the second reservoir may be close to or about equivalent to the hydrostatic pressure of the ocean at the underwater depth of the second reservoir.

[0282] **Figure 46:** An energy storage system which stores electricity by pumping low density liquid into a rigid underwater tank to displace water inside said rigid tank, wherein said water is displaced to an external underwater water reservoir. The present figure shows the present embodiment at a fully charged, steady state. The pressure inside the second reservoir may be close to or about equivalent to the hydrostatic pressure of the ocean at the underwater depth of the second reservoir.

[0283] **Figure 48:** An energy storage system which stores electricity by pumping low density liquid into a rigid underwater tank to displace water inside said rigid tank, wherein said water is displaced to an external underwater water reservoir. The present figure shows the present embodiment at a state of generating electricity or discharging. For example, a valve (“5”) may open, allowing water inside an underwater reservoir (“2”) to displace low density liquid from said underwater reservoir through a pipe (“3”), through a generator (“4”), generating electricity or discharging stored electricity, and into the reservoir near the surface (“1”). The pressure inside the second reservoir may be close to or about equivalent to the hydrostatic pressure of the ocean at the underwater depth of the second reservoir.

[0284] **Figure 49:** An energy storage system which stores electricity by pumping low density liquid into a rigid underwater tank to displace water inside said rigid tank, wherein said water is displaced to an external underwater water reservoir. The present figure shows the present embodiment at a fully discharged, steady state. The pressure inside the second reservoir may be close to or about equivalent to the hydrostatic pressure of the ocean at the underwater depth of the second reservoir.

[0285] **Figure 50:** An energy storage system which stores electricity by pumping low density liquid into an underwater tank (second reservoir) to displace water inside said second reservoir, wherein said water is displaced to an external underwater water reservoir (third reservoir). The present figure shows the present embodiment at a fully discharged, steady state. “2” may represent a rigid underwater tank, which may comprise the second reservoir. “S” may represent a separator or barrier, which may be located between the low density liquid and the water or may physically separate or prevent or minimize direct contact between the low density liquid and the water. Said separator or barrier may prevent direct contact between the low density liquid and water and / or may provide a physical separation between the low density liquid and water. Said separator or barrier may allow the low density liquid to displace the water, while, for example, preventing or minimizing direct contact between the water and the low density liquid. “8” may represent an external water reservoir or the third reservoir. In the present figure, the external water reservoir may be located underwater. In the present figure, the external water reservoir may be underwater at a similar depth to the second reservoir. “9” may represent a water pipe interconnecting an external water reservoir to the second reservoir. In the present figure, the external water reservoir, or the pipe interconnecting the external water reservoir to the second reservoir, or a combination thereof may possess an internal pressure close to the hydrostatic pressure of the ocean water at or near the depth of the second reservoir. The pressure inside the second reservoir may be close to or about equivalent to the hydrostatic pressure of the ocean at the underwater depth of the second reservoir.

[0286] **Figure 51:** An energy storage system which stores electricity by pumping low density liquid into an underwater tank (second reservoir) to displace water inside said second reservoir, wherein said water is displaced to an external underwater water reservoir (third reservoir). The present figure shows the present embodiment at a state of charging, for example, wherein electricity is powering a pump (“4”) to transfer low density liquid from a reservoir near the surface (“1”) to a underwater reservoir (“2”), for example, whereby low density liquid displaces water inside said underwater reservoir. “2” may represent a rigid underwater tank, which may comprise the second reservoir. “S” may represent a separator or barrier, which may be located between the low density liquid and the water or may physically separate or prevent or minimize direct contact between the low density liquid and the water. Said separator or barrier may prevent direct contact between the low density liquid and water and / or may provide a physical separation between the low density liquid and water. Said separator or barrier may allow the low density liquid to displace the water, while, for example, preventing or minimizing direct contact between the water and the

low density liquid. “8” may represent an external water reservoir or the third reservoir. In the present figure, the external water reservoir may be located underwater. In the present figure, the external water reservoir may be underwater at a similar depth to the second reservoir. “9” may represent a water pipe interconnecting an external water reservoir to the second reservoir. In the present figure, the external water reservoir, or the pipe interconnecting the external water reservoir to the second reservoir, or a combination thereof may possess an internal pressure close to the hydrostatic pressure of the ocean water at or near the depth of the second reservoir. The pressure inside the second reservoir may be close to or about equivalent to the hydrostatic pressure of the ocean at the underwater depth of the second reservoir.

[0287] **Figure 52:** An energy storage system which stores electricity by pumping low density liquid into an underwater tank (second reservoir) to displace water inside said second reservoir, wherein said water is displaced to an external underwater water reservoir (third reservoir). The present figure shows the present embodiment at a fully charged, steady state. “2” may represent a rigid underwater tank, which may comprise the second reservoir. “S” may represent a separator or barrier, which may be located between the low density liquid and the water or may physically separate or prevent or minimize direct contact between the low density liquid and the water. Said separator or barrier may prevent direct contact between the low density liquid and water and / or may provide a physical separation between the low density liquid and water. Said separator or barrier may allow the low density liquid to displace the water, while, for example, preventing or minimizing direct contact between the water and the low density liquid. “8” may represent an external water reservoir or the third reservoir. Said physical separation or barrier may comprise a membrane. In the present figure, the external water reservoir may be located underwater. In the present figure, the external water reservoir may be underwater at a similar depth to the second reservoir. “9” may represent a water pipe interconnecting an external water reservoir to the second reservoir. In the present figure, the external water reservoir, or the pipe interconnecting the external water reservoir to the second reservoir, or a combination thereof may possess an internal pressure close to the hydrostatic pressure of the ocean water at or near the depth of the second reservoir. The pressure inside the second reservoir may be close to or about equivalent to the hydrostatic pressure of the ocean at the underwater depth of the second reservoir.

[0288] **Figure 53:** An energy storage system which stores electricity by pumping low density liquid into an underwater tank (second reservoir) to displace water inside said second reservoir, wherein said water is displaced to an external underwater water reservoir (third reservoir). The present figure shows the present embodiment at a state of generating electricity or discharging.

For example, a valve (“5”) may open, allowing water inside an underwater reservoir (“2”) to displace low density liquid from said underwater reservoir through a pipe (“3”), through a generator (“4”), generating electricity or discharging stored electricity, and into the reservoir near the surface (“1”). “2” may represent a rigid underwater tank, which may comprise the second reservoir. “S” may represent a separator or barrier, which may be located between the low density liquid and the water or may physically separate or prevent or minimize direct contact between the low density liquid and the water. Said separator or barrier may prevent direct contact between the low density liquid and water and / or may provide a physical separation between the low density liquid and water. Said separator or barrier may allow the low density liquid to displace the water, while, for example, preventing or minimizing direct contact between the water and the low density liquid. “8” may represent an external water reservoir or the third reservoir. In the present figure, the external water reservoir may be located underwater. In the present figure, the external water reservoir may be underwater at a similar depth to the second reservoir. “9” may represent a water pipe interconnecting an external water reservoir to the second reservoir. In the present figure, the external water reservoir, or the pipe interconnecting the external water reservoir to the second reservoir, or a combination thereof may possess an internal pressure close to the hydrostatic pressure of the ocean water at or near the depth of the second reservoir. The pressure inside the second reservoir may be close to or about equivalent to the hydrostatic pressure of the ocean at the underwater depth of the second reservoir.

[0289] **Figure 54:** An energy storage system which stores electricity by pumping low density liquid into an underwater tank (second reservoir) to displace water inside said second reservoir into a separate water reservoir (third reservoir). The third reservoir may comprise a tank at a higher elevation than the second reservoir and / or a tank which is at a lower elevation than the second reservoir and / or a rigid tank which is mechanically isolated from the water submerging the tank and / or a tank on or above the surface of the water body and / or a tank located on land. The present figure shows the present embodiment at or near a fully discharged, steady state. “2” may comprise an underwater second reservoir, which may comprise low density liquid and water inside an underwater tank. In the second reservoir, the low density liquid may be physically separate from the water by a physical barrier or separator (“S”). The physical barrier or separator may enable low density liquid to exchange pressure with the water, while ensuring the water and low density liquid are physically separate or not in direct contact. The physical barrier or separator may be rigid, or flexible, or a combination thereof. The physical separation or barrier may comprise a membrane. The physical barrier or separator may be removable or replaceable or

adjustable or a combination thereof, which may facilitate operations, or maintenance, or efficiency, or system longevity, or cost, or a combination thereof. Said separator or barrier may prevent direct contact between the low density liquid and water and / or may provide a physical separation between the low density liquid and water. Said separator or barrier may allow the low density liquid to displace the water, while, for example, preventing or minimizing direct contact between the water and the low density liquid. “6” may comprise a third reservoir, which, in the present figure, comprises storage for displaced water and may be located on land. “1” may comprise a first reservoir, which may comprise storage for low density liquid and may be located at a greater elevation than a second reservoir. Electricity may be stored by powering a pump (“4”) to pump low density liquid from the first reservoir through a pipe (“3”) to the second reservoir (“2”) and displace water from the second reservoir through a pipe (“7”) to the third reservoir (“6”). Electricity may be generated or discharged by allowing low density liquid in the second reservoir to be displaced by water from the third reservoir, wherein water from the third reservoir displaces low density liquid from the second reservoir through a pipe (“3”), through a generator (“4”), generating electricity, and into the first reservoir. The pump and generator may comprise the same unit(s) which can reversibly function as a pump and a generator, which may comprise a hydraulic power recovery turbine (HPRT). The pressure inside the second reservoir may be close to or about equivalent to the hydrostatic pressure of the ocean at the underwater depth of the second reservoir.

[0290] Figure 55: An energy storage system which stores electricity by pumping low density liquid into an underwater tank (second reservoir) to displace water inside said second reservoir into a separate water reservoir (third reservoir). The third reservoir may comprise a tank at a higher elevation than the second reservoir and / or a tank which is at a lower elevation than the second reservoir and / or a rigid tank which is mechanically isolated from the water submerging the tank and / or a tank on or above the surface of the water body and / or a tank located on land. The present figure shows the present embodiment at a state of storing electricity or charging, wherein electricity may be stored by powering a pump to transfer low density liquid from the first reservoir to the second reservoir, displacing water in the second reservoir. “2” may comprise an underwater second reservoir, which may comprise low density liquid and water inside an underwater tank. In the second reservoir, the low density liquid may be physically separate from the water by a physical barrier or separator (“S”). The physical barrier or separator may enable low density liquid to exchange pressure with the water, while ensuring the water and low density liquid are physically separate or not in direct contact. The physical barrier or separator may be rigid, or flexible, or a combination thereof. The physical barrier or separator may be removable or replaceable or

adjustable or a combination thereof, which may facilitate operations, or maintenance, or efficiency, or system longevity, or cost, or a combination thereof. Said separator or barrier may prevent direct contact between the low density liquid and water and / or may provide a physical separation between the low density liquid and water. Said separator or barrier may allow the low density liquid to displace the water, while, for example, preventing or minimizing direct contact between the water and the low density liquid. “6” may comprise a third reservoir, which, in the present figure, comprises storage for displaced water and may be located on land. “1” may comprise a first reservoir, which may comprise storage for low density liquid and may be located at a greater elevation than a second reservoir. Electricity may be stored by powering a pump (“4”) to pump low density liquid from the first reservoir through a pipe (“3”) to the second reservoir (“2”) and displace water from the second reservoir through a pipe (“7”) to the third reservoir (“6”). Electricity may be generated or discharged by allowing low density liquid in the second reservoir to be displaced by water from the third reservoir, wherein water from the third reservoir displaces low density liquid from the second reservoir through a pipe (“3”), through a generator (“4”), generating electricity, and into the first reservoir. The pump and generator may comprise the same unit(s) which can reversibly function as a pump and a generator, which may comprise a hydraulic power recovery turbine (HPRT). The pressure inside the second reservoir may be close to or about equivalent to the hydrostatic pressure of the ocean at the underwater depth of the second reservoir.

[0291] **Figure 56:** An energy storage system which stores electricity by pumping low density liquid into an underwater tank (second reservoir) to displace water inside said second reservoir into a separate water reservoir (third reservoir). The third reservoir may comprise a tank at a higher elevation than the second reservoir and / or a tank which is at a lower elevation than the second reservoir and / or a rigid tank which is mechanically isolated from the water submerging the tank and / or a tank on or above the surface of the water body and / or a tank located on land. The present figure shows the present embodiment at or near a fully charged, steady state. “2” may comprise an underwater second reservoir, which may comprise low density liquid and water inside an underwater tank. In the second reservoir, the low density liquid may be physically separate from the water by a physical barrier or separator (“S”). The physical barrier or separator may enable low density liquid to exchange pressure with the water, while ensuring the water and low density liquid are physically separate or not in direct contact. The physical barrier or separator may be rigid, or flexible, or a combination thereof. The physical barrier or separator may be removable or replaceable or adjustable or a combination thereof, which may facilitate operations, or maintenance, or efficiency, or system longevity, or cost, or a combination thereof. Said

separator or barrier may prevent direct contact between the low density liquid and water and / or may provide a physical separation between the low density liquid and water. Said separator or barrier may allow the low density liquid to displace the water, while, for example, preventing or minimizing direct contact between the water and the low density liquid. “6” may comprise a third reservoir, which, in the present figure, comprises storage for displaced water and may be located on land. “1” may comprise a first reservoir, which may comprise storage for low density liquid and may be located at a greater elevation than a second reservoir. Electricity may be stored by powering a pump (“4”) to pump low density liquid from the first reservoir through a pipe (“3”) to the second reservoir (“2”) and displace water from the second reservoir through a pipe (“7”) to the third reservoir (“6”). Electricity may be generated or discharged by allowing low density liquid in the second reservoir to be displaced by water from the third reservoir, wherein water from the third reservoir displaces low density liquid from the second reservoir through a pipe (“3”), through a generator (“4”), generating electricity, and into the first reservoir. The pump and generator may comprise the same unit(s) which can reversibly function as a pump and a generator, which may comprise a hydraulic power recovery turbine (HPRT). The pressure inside the second reservoir may be close to or about equivalent to the hydrostatic pressure of the ocean at the underwater depth of the second reservoir.

[0292] Figure 57: An energy storage system which stores electricity by pumping low density liquid into an underwater tank (second reservoir) to displace water inside said second reservoir into a separate water reservoir (third reservoir). The third reservoir may comprise a tank at a higher elevation than the second reservoir and / or a tank which is at a lower elevation than the second reservoir and / or a rigid tank which is mechanically isolated from the water submerging the tank and / or a tank on or above the surface of the water body and / or a tank located on land. The present figure shows the present embodiment at an electricity generating or discharging state. Electricity may be generated by allowing low density liquid to be displaced from the second reservoir, through a pipe, into a generator, generating electricity, and into the first reservoir. Low density liquid in the second reservoir may be allowed to be displaced by water. Said allowing may involve opening a valve (“5”) in a low density liquid pipe. “2” may comprise an underwater second reservoir, which may comprise low density liquid and water inside an underwater tank. In the second reservoir, the low density liquid may be physically separate from the water by a physical barrier or separator (“S”). The physical barrier or separator may enable low density liquid to exchange pressure with the water, while ensuring the water and low density liquid are physically separate or not in direct contact. The physical barrier or separator may be rigid, or flexible, or a

combination thereof. The physical barrier or separator may be removable or replaceable or adjustable or a combination thereof, which may facilitate operations, or maintenance, or efficiency, or system longevity, or cost, or a combination thereof. Said separator or barrier may prevent direct contact between the low density liquid and water and / or may provide a physical separation between the low density liquid and water. Said separator or barrier may allow the low density liquid to displace the water, while, for example, preventing or minimizing direct contact between the water and the low density liquid. “6” may comprise a third reservoir, which, in the present figure, comprises storage for displaced water and may be located on land. “1” may comprise a first reservoir, which may comprise storage for low density liquid and may be located at a greater elevation than a second reservoir. Electricity may be stored by powering a pump (“4”) to pump low density liquid from the first reservoir through a pipe (“3”) to the second reservoir (“2”) and displace water from the second reservoir through a pipe (“7”) to the third reservoir (“6”). Electricity may be generated or discharged by allowing low density liquid in the second reservoir to be displaced by water from the third reservoir, wherein water from the third reservoir displaces low density liquid from the second reservoir through a pipe (“3”), through a generator (“4”), generating electricity, and into the first reservoir. The pump and generator may comprise the same unit(s) which can reversibly function as a pump and a generator, which may comprise a hydraulic power recovery turbine (HPRT). The pressure inside the second reservoir may be close to or about equivalent to the hydrostatic pressure of the ocean at the underwater depth of the second reservoir.

[0293] **Figure 58:** An energy storage system which stores electricity by pumping low density liquid into an underwater tank (“2”) (second reservoir) to displace water inside said second reservoir into a separate water reservoir (“8”) (third reservoir). The second reservoir may comprise an underwater rigid tank which may contain both low density liquid and water. Inside said second reservoir, low density liquid may be stored in a sub-reservoir or sub-tank (“10”) which may comprise an expandable or collapsible structure, such as a bladder tank or piston or a combination thereof. Said sub-tank may be employed to prevent direct contact between low density liquid and water in the second reservoir. In the event the internal sub-tank breaks or leaks, the leaked low density liquid may remain inside this rigid tank or rigid containment structure, preventing exposure of the low density liquid to the surrounding environment. Said sub-tank may be considered a physical barrier or separator, and may be removable or replaceable or adjustable or a combination thereof, which may facilitate operations, or maintenance, or efficiency, or system longevity, or cost, or a combination thereof. The present figure shows the present embodiment at a near fully discharged state. The third reservoir, which may be connected to the second reservoir using a pipe,

may comprise nearby ocean water, or a water tank at pressure equilibrium with the ocean, or a rigid water tank mechanically isolated from nearby ocean and at similar pressure to the hydrostatic pressure of the nearby ocean, or a water tank on or near the ocean surface, or a water tank on land. If the third reservoir is at pressure equilibrium with the surrounding ocean and / or the density of the liquid inside the third reservoir is close to the density of ocean water, the third reservoir may be located at any elevation relative to the second reservoir. For example, the third reservoir may be located at the same elevation as or similar elevation to the second reservoir, as is shown in the present figure. For example, the third reservoir may be located at a deeper depth or lower elevation than the second reservoir. For example, the third reservoir may be located at a shallower depth or greater elevation than the second reservoir. For example, the third reservoir may be located on land. Electricity may be stored by powering a pump ("4") to pump low density liquid from the first reservoir through a pipe ("3") to the second reservoir ("2") and displace water from the second reservoir through a pipe ("7") to the third reservoir ("6"). Electricity may be stored by powering a pump ("4") to pump low density liquid from the first reservoir through a pipe ("3") to the second reservoir ("2"), specifically the low density liquid second reservoir sub-tank ("10"), and displace water from the second reservoir through a pipe ("9") to a third reservoir ("8"). Electricity may be generated or discharged by allowing low density liquid in the second reservoir, specifically the low density liquid second reservoir sub-tank ("10"), to be displaced by water from the third reservoir, wherein water from the third reservoir displaces low density liquid from the second reservoir through a pipe ("3"), through a generator ("4"), generating electricity, and into the first reservoir ("1"). The pump and generator may comprise the same unit(s) which can reversibly function as a pump and a generator, which may comprise a hydraulic power recovery turbine (HPRT). The pressure inside the second reservoir may be close to or about equivalent to the hydrostatic pressure of the ocean at the underwater depth of the second reservoir.

[0294] An electricity storage system with a surface tank ('1'), an underwater rigid tank ('2'), a bladder sub-tank configured to store low density liquid ('10'), and an interconnected external bladder tank configured to store water ('8').

[0295] The present embodiment at a nearly fully discharged state.

[0296] **Figure 59:** An energy storage system which stores electricity by pumping low density liquid into an underwater tank ("2") (second reservoir) to displace water inside said second reservoir into a separate water reservoir ("8") (third reservoir). The second reservoir may comprise an underwater rigid tank which may contain both low density liquid and water. Inside said second reservoir, low density liquid may be stored in a sub-reservoir or sub-tank ("10") which may

comprise an expandable or collapsible structure, such as a bladder tank or piston or a combination thereof. Said sub-tank may be employed to prevent direct contact between low density liquid and water in the second reservoir. In the event the internal sub-tank breaks or leaks, the leaked low density liquid may remain inside this rigid tank or rigid containment structure, preventing exposure of the low density liquid to the surrounding environment. Said sub-tank may be considered a physical barrier or separator, and may be removable or replaceable or adjustable or a combination thereof, which may facilitate operations, or maintenance, or efficiency, or system longevity, or cost, or a combination thereof. The present figure shows the present embodiment storing electricity or 'charging', wherein low density liquid is pumped from the first reservoir to the second reservoir, displacing water from the second reservoir into the third reservoir. The third reservoir, which may be connected to the second reservoir using a pipe, may comprise nearby ocean water, or a water tank at pressure equilibrium with the ocean, or a rigid water tank mechanically isolated from nearby ocean and at similar pressure to the hydrostatic pressure of the nearby ocean, or a water tank on or near the ocean surface, or a water tank on land. If the third reservoir is at pressure equilibrium with the surrounding ocean and / or the density of the liquid inside the third reservoir is close to the density of ocean water, the third reservoir may be located at any elevation relative to the second reservoir. For example, the third reservoir may be located at the same elevation as or similar elevation to the second reservoir, as is shown in the present figure. For example, the third reservoir may be located at a deeper depth or lower elevation than the second reservoir. For example, the third reservoir may be located at a shallower depth or greater elevation than the second reservoir. For example, the third reservoir may be located on land. Electricity may be stored by powering a pump ("4") to pump low density liquid from the first reservoir through a pipe ("3") to the second reservoir ("2") and displace water from the second reservoir through a pipe ("7") to the third reservoir ("6"). Electricity may be stored by powering a pump ("4") to pump low density liquid from the first reservoir through a pipe ("3") to the second reservoir ("2"), specifically the low density liquid second reservoir sub-tank ("10"), and displace water from the second reservoir through a pipe ("9") to a third reservoir ("8"). Electricity may be generated or discharged by allowing low density liquid in the second reservoir, specifically the low density liquid second reservoir sub-tank ("10"), to be displaced by water from the third reservoir, wherein water from the third reservoir displaces low density liquid from the second reservoir through a pipe ("3"), through a generator ("4"), generating electricity, and into the first reservoir ("1"). The pump and generator may comprise the same unit(s) which can reversibly function as a pump and a generator, which may comprise a hydraulic power recovery turbine

(HPRT). The pressure inside the second reservoir may be close to or about equivalent to the hydrostatic pressure of the ocean at the underwater depth of the second reservoir.

[0297] The present embodiment storing electricity ('charging'). Low density liquid is pumped ('4') from the surface tank ('1'), through a pipe ('3'), to the underwater rigid tank ('2'), displacing water in the underwater rigid tank ('2'). The displaced water travels through a pipe ('9') into the external bladder tank ('8').

[0298] **Figure 60:** An energy storage system which stores electricity by pumping low density liquid into an underwater tank ("2") (second reservoir) to displace water inside said second reservoir into a separate water reservoir ("8") (third reservoir). The second reservoir may comprise an underwater rigid tank which may contain both low density liquid and water. Inside said second reservoir, low density liquid may be stored in a sub-reservoir or sub-tank ("10") which may comprise an expandable or collapsible structure, such as a bladder tank or piston or a combination thereof. Said sub-tank may be employed to prevent direct contact between low density liquid and water in the second reservoir. In the event the internal sub-tank breaks or leaks, the leaked low density liquid may remain inside this rigid tank or rigid containment structure, preventing exposure of the low density liquid to the surrounding environment. Said sub-tank may be considered a physical barrier or separator, and may be removable or replaceable or adjustable or a combination thereof, which may facilitate operations, or maintenance, or efficiency, or system longevity, or cost, or a combination thereof. The present figure shows the present embodiment at a near fully charged state. The third reservoir, which may be connected to the second reservoir using a pipe, may comprise nearby ocean water, or a water tank at pressure equilibrium with the ocean, or a rigid water tank mechanically isolated from nearby ocean and at similar pressure to the hydrostatic pressure of the nearby ocean, or a water tank on or near the ocean surface, or a water tank on land. If the third reservoir is at pressure equilibrium with the surrounding ocean and / or the density of the liquid inside the third reservoir is close to the density of ocean water, the third reservoir may be located at any elevation relative to the second reservoir. For example, the third reservoir may be located at the same elevation as or similar elevation to the second reservoir, as is shown in the present figure. For example, the third reservoir may be located at a deeper depth or lower elevation than the second reservoir. For example, the third reservoir may be located at a shallower depth or greater elevation than the second reservoir. For example, the third reservoir may be located on land. Electricity may be stored by powering a pump ("4") to pump low density liquid from the first reservoir through a pipe ("3") to the second reservoir ("2") and displace water from the second reservoir through a pipe ("7") to the third reservoir ("6"). Electricity may be stored by powering

a pump (“4”) to pump low density liquid from the first reservoir through a pipe (“3”) to the second reservoir (“2”), specifically the low density liquid second reservoir sub-tank (“10”), and displace water from the second reservoir through a pipe (“9”) to a third reservoir (“8”). Electricity may be generated or discharged by allowing low density liquid in the second reservoir, specifically the low density liquid second reservoir sub-tank (“10”), to be displaced by water from the third reservoir, wherein water from the third reservoir displaces low density liquid from the second reservoir through a pipe (“3”), through a generator (“4”), generating electricity, and into the first reservoir (“1”). The pump and generator may comprise the same unit(s) which can reversibly function as a pump and a generator, which may comprise a hydraulic power recovery turbine (HPRT). The pressure inside the second reservoir may be close to or about equivalent to the hydrostatic pressure of the ocean at the underwater depth of the second reservoir.

[0299] The present embodiment at a nearly fully charged state.

[0300] **Figure 61:** An energy storage system which stores electricity by pumping low density liquid into an underwater tank (“2”) (second reservoir) to displace water inside said second reservoir into a separate water reservoir (“8”) (third reservoir). The second reservoir may comprise an underwater rigid tank which may contain both low density liquid and water. Inside said second reservoir, low density liquid may be stored in a sub-reservoir or sub-tank (“10”) which may comprise an expandable or collapsible structure, such as a bladder tank or piston or a combination thereof. Said sub-tank may be employed to prevent direct contact between low density liquid and water in the second reservoir. In the event the internal sub-tank breaks or leaks, the leaked low density liquid may remain inside this rigid tank or rigid containment structure, preventing exposure of the low density liquid to the surrounding environment. Said sub-tank may be considered a physical barrier or separator, and may be removable or replaceable or adjustable or a combination thereof, which may facilitate operations, or maintenance, or efficiency, or system longevity, or cost, or a combination thereof. The present figure shows the present embodiment generating electricity or ‘discharging’. For example, discharging may involve allowing low density liquid in the second reservoir to be displaced by water in the third reservoir, and wherein said low density liquid is displaced into a pipe, into a generator, generating electricity, and into the first reservoir. The third reservoir, which may be connected to the second reservoir using a pipe, may comprise nearby ocean water, or a water tank at pressure equilibrium with the ocean, or a rigid water tank mechanically isolated from nearby ocean and at similar pressure to the hydrostatic pressure of the nearby ocean, or a water tank on or near the ocean surface, or a water tank on land. If the third reservoir is at pressure equilibrium with the surrounding ocean and / or the density of the liquid

inside the third reservoir is close to the density of ocean water, the third reservoir may be located at any elevation relative to the second reservoir. For example, the third reservoir may be located at the same elevation as or similar elevation to the second reservoir, as is shown in the present figure. For example, the third reservoir may be located at a deeper depth or lower elevation than the second reservoir. For example, the third reservoir may be located at a shallower depth or greater elevation than the second reservoir. For example, the third reservoir may be located on land. Electricity may be stored by powering a pump (“4”) to pump low density liquid from the first reservoir through a pipe (“3”) to the second reservoir (“2”) and displace water from the second reservoir through a pipe (“7”) to the third reservoir (“6”). Electricity may be stored by powering a pump (“4”) to pump low density liquid from the first reservoir through a pipe (“3”) to the second reservoir (“2”), specifically the low density liquid second reservoir sub-tank (“10”), and displace water from the second reservoir through a pipe (“9”) to a third reservoir (“8”). Electricity may be generated or discharged by allowing low density liquid in the second reservoir, specifically the low density liquid second reservoir sub-tank (“10”), to be displaced by water from the third reservoir, wherein water from the third reservoir displaces low density liquid from the second reservoir through a pipe (“3”), through a generator (“4”), generating electricity, and into the first reservoir (“1”). The pump and generator may comprise the same unit(s) which can reversibly function as a pump and a generator, which may comprise a hydraulic power recovery turbine (HPRT). The pressure inside the second reservoir may be close to or about equivalent to the hydrostatic pressure of the ocean at the underwater depth of the second reservoir.

[0301] The present embodiment generating electricity (‘discharging’). Water in the external bladder tank (‘8’) is allowed to displace low density liquid in the underwater rigid tank (‘2’). The displaced low density liquid travels through a pipe (‘3’), through a generator (‘4’), to the surface tank (‘1’).

[0302] **Figure 62:** The present figure may comprise a similar embodiment to Figures 58 – 61. The present figure may show the present embodiment as a near fully discharged state. The present figure may employ a third reservoir comprising nearby ocean water or open ocean water. The sub-tank within the second reservoir (“10”), the second reservoir, and the external water pipe connected to the second reservoir (“11”) may be configured such that when low density liquid is pumped into “10”, water displaced from the second reservoir exits the second reservoir in a manner which prevents low density liquid from exiting the second reservoir in the event of a release or leak of low density liquid. For example, said configuration may comprise a pipe and / or tank setup such that a liquid or material exiting the tank must have a density greater than or equal to or close to the

density of water. For example, said configuration may involve the external water pipe “11” possessing an outlet or external outlet which faces toward the seafloor or faces downward or a bend which faces downward. For example, said configuration may involve the external water pipe “11” possessing a pipe inside the underwater tank which has a bend upward and / or faces upward and / or faces toward the sea surface and / or faces away from the seafloor and / or possesses an opening inside the underwater tank which faces upward. For example, said configuration may involve the external water pipe containing a chemical or reagent or material which will swell or absorb low density liquid or react with low density liquid when in presence or contact with low density liquid, which may occur in the event of, for example, a low density liquid leak or release from the sub-tank, which may, for example, trigger the closure of a valve inside the pipe or passively clog or close the pipe or a combination thereof in the event of a low density liquid leak or release from the sub-tank. “11” may be removable or replaceable. The second reservoir internal sub-tank, or the external water pipe, or the third reservoir (if comprising a tank), or a combination thereof may be removable, or replicable. For example, second reservoir internal sub-tank, or the external water pipe, or the third reservoir (if comprising a tank), or a combination thereof may be removed or replaced while the second storage reservoir remains in operation. For example, second reservoir internal sub-tank, or the external water pipe, or the third reservoir (if comprising a tank), or a combination thereof may be removed or replaced while the second storage reservoir remains installed. For example, second reservoir internal sub-tank, or the external water pipe, or the third reservoir (if comprising a tank), or a combination thereof may be removed or replaced or maintained while one or more components remain installed and / or operating, which may include one or more or a combination of the previously described components or other parts of the present invention described herein.

[0303] An electricity storage system with a surface tank (‘1’), an underwater rigid tank (‘2’), and a bladder sub-tank configured to store low density liquid (‘10’). The underwater rigid tank (‘2’) is in direct fluid communication with the adjacent deep sea ocean water by a pipe (‘11’).

[0304] The present embodiment at a nearly fully discharged state.

[0305] Figure 63: The present figure may comprise the embodiment described in the description of Figure 62. The present figure shows the present embodiment at a state of ‘charging’ or storing energy or electricity. Charging may involve pumping low density liquid from the first reservoir to the second reservoir, displacing water in the second reservoir. Water may exit the second reservoir during said displacing such that, even if even the low density liquid leaks from

the internal sub-tank within the second reservoir, the low density liquid may remain in the second reservoir.

[0306] The present embodiment storing electricity ('charging'). Low density liquid is pumped ('4') from the surface tank ('1'), through a pipe ('3'), to the underwater rigid tank ('2'), displacing ocean water from the underwater rigid tank ('2'). The displaced ocean water travels through a pipe ('11') into the ocean adjacent the underwater rigid tank ('2').

[0307] **Figure 64:** The present figure may comprise the embodiment described in the description of Figure 62. The present figure shows the present embodiment at a nearly fully charged state.

[0308] **Figure 65:** The present figure may comprise the embodiment described in the description of Figure 62. The present figure shows the present embodiment at a state of 'discharging' or generating energy or generating electricity. Discharging may involve allowing low density liquid to be displaced from the second reservoir into a pipe, through a generator, generating electricity, and into the first reservoir. Said displacing may involve ocean water passing through a pipe ("11") into the second reservoir. Water may exit the second reservoir during said displacing such that, even if even the low density liquid leaks from the internal sub-tank within the second reservoir, the low density liquid may remain in the second reservoir.

[0309] The present embodiment generating electricity ('discharging'). Ocean water adjacent to the underwater tank in direct fluid communication with the underwater rigid tank ('2') through a pipe ('11') is allowed to displace low density liquid in the underwater rigid tank ('2'). The displaced low density liquid travels through a pipe ('3'), through a generator ('4'), to the surface tank ('1').

[0310] **Figure 66:** An energy storage embodiment with a second reservoir and / or third reservoir with a containment cover or containment barrier ("CB" or "CCB"). Said CB may comprise a cover located over or above one or more components of the system. Said CB may comprise a cover located over or above components of the system which may hold or contain low density liquid. In the event low density liquid escapes from the second reservoir, the low density liquid may float upward, due to, for example, its low density than the water, and may be captured by the CB.

[0311] **Figure 67:** An energy storage embodiment with a second reservoir and / or third reservoir with a containment cover or containment barrier ("CB" or "CCB"). Said CB may comprise a cover located over or above one or more components of the system. Said CB may comprise a cover located over or above components of the system which may hold or contain low

density liquid. In the event low density liquid escapes from the second reservoir, the low density liquid may float upward, due to, for example, its low density than the water, and may be captured by the CB.

[0312] Figure 68: An energy storage embodiment with a second reservoir and / or third reservoir with a containment cover or containment barrier (“CB” or “CCB”). Said CB may comprise a cover located over or above one or more components of the system. Said CB may comprise a cover located over or above components of the system which may hold or contain low density liquid. In the event low density liquid escapes from the second reservoir, the low density liquid may float upward, due to, for example, its low density than the water, and may be captured by the CB.

[0313] Figure 69: An energy storage embodiment with a second reservoir and / or third reservoir with a containment cover or containment barrier (“CB” or “CCB”). Said CB may comprise a cover located over or above one or more components of the system. Said CB may comprise a cover located over or above components of the system which may hold or contain low density liquid. In the event low density liquid escapes from the second reservoir, the low density liquid may float upward, due to, for example, its low density than the water, and may be captured by the CB. In the present figure, “S” may comprise a separator or barrier, which may prevent or minimize the physical or direct contact between low density liquid and water within the second reservoir.

[0314] Figure 70: An energy storage system which stores electricity by pumping low density liquid into a sub-tank (“5”) within a second reservoir (“2”) to displace water inside said second reservoir. The second reservoir may comprise a rigid tank or rigid containment structure, which may surround or contain a sub-tank (“5”) configured to store low density liquid. Said sub-tank may comprise an expandable or collapsible tank. Said sub-tank may be situated above a water port or hole or pipe or the outlet or a combination thereof to, for example, ensure low density liquid remains in the second reservoir in the event of a leak or accidental release of low density liquid. Said water port or hole or pipe or the outlet or a combination thereof may be employed to enable displaced water during the ‘storing’ of electricity to exit the second reservoir; and / or enable water to enter the second reservoir to displace low density liquid during the discharging or generating of electricity. The sub-tank may comprise a membrane or membrane-like structure. A rigid tank or rigid containment structure may surround the sub-tank and / or cover the top portion of the sub-tank. An example characteristic of the rigid tank or rigid containment structure may comprise the ability to control the entering or exiting of water or other liquids or substances from the second

reservoir, which may include, but is not limited to, the ability to open or close a valve or port which may enable or disable or both the flow of water, or other liquids or other substances to and / or from the second reservoir. The present figure shows the present embodiment ‘charging’/. Said charging may involve pumping low density liquid from the first reservoir to the second reservoir, displacing water from the second reservoir with the low density liquid.

[0315] Figure 71: An energy storage system which stores electricity by pumping low density liquid into a sub-tank (“5”) within a second reservoir (“2”) to displace water inside said second reservoir. The second reservoir may comprise a rigid tank or rigid containment structure, which may surround or contain a sub-tank (“5”) configured to store low density liquid. Said sub-tank may comprise an expandable or collapsible tank. Said sub-tank may be situated above a water port or hole or pipe or the outlet or a combination thereof to, for example, ensure low density liquid remains in the second reservoir in the event of a leak or accidental release of low density liquid. Said water port or hole or pipe or the outlet or a combination thereof may be employed to enable displaced water during the ‘storing’ of electricity to exit the second reservoir; and / or enable water to enter the second reservoir to displace low density liquid during the discharging or generating of electricity. A rigid tank or rigid containment structure may surround the sub-tank and / or cover the top portion of the sub-tank. An example characteristic of the rigid tank or rigid containment structure may comprise the ability to control the entering or exiting of water or other liquids or substances from the second reservoir, which may include, but is not limited to, the ability to open or close a valve or port which may enable or disable or both the flow of water, or other liquids or other substances to and / or from the second reservoir. The present figure shows the present embodiment at a nearly fully charged state.

[0316] Figure 72: An energy storage system which stores electricity by pumping low density liquid into a sub-tank (“5”) within a second reservoir (“2”) to displace water inside said second reservoir. The second reservoir may comprise a rigid tank or rigid containment structure, which may surround or contain a sub-tank (“5”) configured to store low density liquid. Said sub-tank may comprise an expandable or collapsible tank. Said sub-tank may be situated above a water port or hole or pipe or the outlet or a combination thereof to, for example, ensure low density liquid remains in the second reservoir in the event of a leak or accidental release of low density liquid. Said water port or hole or pipe or the outlet or a combination thereof may be employed to enable displaced water during the ‘storing’ of electricity to exit the second reservoir; and / or enable water to enter the second reservoir to displace low density liquid during the discharging or generating of electricity. A rigid tank or rigid containment structure may surround the sub-tank and / or cover

the top portion of the sub-tank. An example characteristic of the rigid tank or rigid containment structure may comprise the ability to control the entering or exiting of water or other liquids or substances from the second reservoir, which may include, but is not limited to, the ability to open or close a valve or port which may enable or disable or both the flow of water, or other liquids or other substances to and / or from the second reservoir. The present figure shows the present embodiment discharging or generating electricity. Discharging or generating electricity may involve low density liquid from the second reservoir being displaced into a pipe, through a generator, generating electricity and into the first reservoir. The displacement of low density liquid from the second reservoir may be allowed by opening a valve near or within the pump or generator or a valve near or within the second reservoir tank or a combination thereof. The displacement of low density liquid in the second reservoir may comprise water entering the second reservoir and displacing the low density liquid in the second reservoir.

[0317] **Figure 73:** An energy storage system which stores electricity by pumping low density liquid into a sub-tank (“5”) within a second reservoir (“2”) to displace water inside said second reservoir. The second reservoir may comprise a rigid tank or rigid containment structure, which may surround or contain a sub-tank (“5”) configured to store low density liquid. Said sub-tank may comprise an expandable or collapsible tank. Said sub-tank may be situated above a water port or hole or pipe or the outlet or a combination thereof to, for example, ensure low density liquid remains in the second reservoir in the event of a leak or accidental release of low density liquid. Said water port or hole or pipe or the outlet or a combination thereof may be employed to enable displaced water during the ‘storing’ of electricity to exit the second reservoir; and / or enable water to enter the second reservoir to displace low density liquid during the discharging or generating of electricity. A rigid tank or rigid containment structure may surround the sub-tank and / or cover the top portion of the sub-tank. An example characteristic of the rigid tank or rigid containment structure may comprise the ability to control the entering or exiting of water or other liquids or substances from the second reservoir, which may include, but is not limited to, the ability to open or close a valve or port which may enable or disable or both the flow of water, or other liquids or other substances to and / or from the second reservoir. The present figure shows the present embodiment at a nearly fully discharged state.

[0318] **Figure 74:** The present figure shows the present embodiment charging or storing electricity. The present figure shows an embodiment where the first reservoir (“1”) and / or pump (“4”) and / or generator (“4”) is located underwater at a higher elevation or lesser water depth than the second reservoir. The first reservoir may comprise a rigid tank or a bladder tank. In the present

figure, the first reservoir is shown as a rigid tank. In the present embodiment shown in the present figure, a subsea power cable (“15”) connects the pump and / or generator (“4”) to electricity power sources, and / or electricity demand sources, and / or an electricity grid. Electricity power sources, and / or electricity demand sources, and / or an electricity grid, which may include transmission infrastructure, may be represented by “13” and “14” in the present figure and may be located on land or underwater. The subsea power cable may interconnect the present energy storage system with offshore power sources, such as, for example, including, but not limited to, one or more or a combination of the following: offshore wind, offshore solar, and offshore rigs, offshore generating, or other power sources. The subsea power cable may interconnect the present energy storage system with offshore demand sources, such as, for example, including, but not limited to, offshore pipelines, offshore transmission stations, offshore compression stations, offshore drilling, heated flow lines, offshore oil rigs, offshore production systems, hydrogen production, ammonia production, CO₂ conversion, gas processing facilities, and / or other energy consumption sources. The subsea power cable may interconnect the present energy storage system with on-shore energy demand and on-shore power production sources, which may include, but are not limited to, one or more or a combination of the following: industrial electricity demand, commercial electricity demand, residential electricity demand, transportation electricity demand, renewable power sources, residential power sources, electricity grid load balancing, electricity grid services, on-shore solar plant, on-shore wind, on-shore hydropower, on-shore combustion power generation, hydrogen production, storing excess renewable electricity, discharging electricity during peak demand or when intermittent renewables are underproducing power. The present figure may show an energy storage system which stores electricity by pumping low density liquid into a sub-tank (“5”) within a second reservoir (“2”) to displace water inside said second reservoir.

[0319] The present embodiment leverages multiple aspects of the technical limitations of offshore technologies, and the geography of many offshore regions.

- The offshore seafloor in most of the world is relatively shallow within 10 miles, or 20 miles, or 30 miles, or 40 miles or 50 miles, or 60 miles or 70 miles, or 80 miles, or 90 miles, or 100 miles or a combination thereof of shore. Relatively shallow water depth may comprise a water depth less deep than 1,000 meters, or 900 meters, or 800 meters, or 700 meters, or 600 meters, or 500 meters, or 400 meters, or 300 meters, or 200 meters, or 100 meters or a combination thereof. Furthermore, in most geographies, said relatively shallow water eventually reaches a precipitous ledge or continental shelf, which drops to a water depth of 1,500 meters, or 2,000 meters, or 2,500 meters, or 3,000 meters, or even greater

depths. The present embodiment places the first reservoir and / or pump and generator at a near said ledge or continental shelf, which may minimize the length of the pipeline from the first reservoir to the second reservoir. Minimizing the length of the pipeline increases round-trip energy efficiency and reduces capital cost.

- In the present embodiment, the pump and / or generator may be interconnected to a power source or power demand or an electricity grid or a combination thereof by a subsea power cable. Subsea power cables are least expensive and / or simplest to install on relatively shallow and / or relatively flat subsea terrain. The subsea cable in the present may be installed on relatively shallow and / or relatively flat subsea terrain.
- Modern day offshore wind farms require relatively shallow water depths, generally less than 1,000 meters in water depth, to be economically viable. The present embodiment enables the present invention to be integrated with current day offshore wind farms by being located relatively close to shallow water ideal for offshore wind farms. Also, by being able to co-locate with offshore wind or offshore solar or offshore rigs or a combination thereof, the present invention may integrate with pre-existing or pre-planned subsea power cables or power transmission infrastructure. Alternatively, or additionally, by being able to co-locate with offshore wind or offshore solar or offshore rigs or other offshore technologies, the present invention may improve the economics of said technologies and other technologies, facilitating the construction of the subsea power infrastructure and / or the present invention. For example, offshore Virginia, North Carolina, Delaware, and Maryland (all locations with proposed offshore wind farms) possess shallow water and a nearby precipitous ledges and / or continental shelf.
- Due to the first reservoir and / or generating being located 'offshore', the only 'shore crossing infrastructure' in the present embodiment may be a subsea power cable and related transmission interconnections and infrastructure. The minimal 'shore crossing' and 'on-shore' infrastructure of the present embodiment may reduce the required permitting and / or approvals and / or timeline and / or regulatory bodies. Additionally, the lack of tanks or generators on-shore may enable the present embodiment to occupy less onshore land and / or may enable the present embodiment to be less visually obvious and / or make the present embodiment more visually appealing
- In the present embodiment, the first reservoir and / or pump and / or generator may be located at a water depth sufficiently deep to be minimally exposed to ocean waves and / or ocean weather. In the present embodiment, the first reservoir and / or pump and / or

generator may be located at a water depth sufficiently shallow to enable a significant elevation difference between the first and second reservoirs. For example, a significant elevation difference may comprise an elevation or depth difference greater than or equal to 500 meters, or 1,000 meters, or 1,500 meters, or 2,000 meters. In the present embodiment, it may be advantageous for the first reservoir and / or pump and / or generator may be located at a water depth sufficiently shallow to enable professional divers and / or professional diving vessels access or convenient access for monitoring and / or maintenance.

- The present embodiment possesses practically limitless land area and / or geographic area for energy storage. The amount of subsea seafloor with suitable geography vastly exceeds the seafloor land area required for multi-hour, or multi-day, or even multi-month electricity storage using the present embodiment.

[0320] Figure 75: The present figure comprises the same embodiment as Figure 74. The present figure shows the present embodiment at a nearly fully charged state.

[0321] Figure 76: The present figure comprises the same embodiment as Figure 74. The present figure shows the present embodiment discharging or generating electricity.

[0322] Figure 77: The present figure comprises the same embodiment as Figure 74. The present figure shows the present embodiment at a nearly fully discharged state.

[0323] Figure 78: The present figure shows the present embodiment charging or storing electricity. The present figure shows an embodiment where the first reservoir (“1”) and / or pump (“4”) and / or generator (“4”) is located in a floating vessel (“16”). Said floating vessel may comprise a carrier, or a carrier retrofitted to enable greater unloading or loading flow rates than conventional carriers, or a specially designed carrier, or a combination thereof. Said carrier may comprise a ship, such as, for example, an LPG carrier. Said floating vessel may be interconnected to a subsea power cable and / or subsea low density liquid pipeline using or facilitated by one or more buoys. For example, the present figure may show the low density liquid pipeline interconnect buoy as “L” and the subsea cable electricity interconnect buoy as “X”. One or more or multiple or a combination of subsea pipelines, floating vessels, buoys, subsea tanks, or subsea tanks may be employed.

[0324] Floating vessels may be connectable or disconnectable or both. Floating vessels may be connectable or disconnectable to each other. Floating vessels may be connectable or disconnectable to or from floating buoys. For example, said floating vessels may be added or removed (connected or disconnected) when more or less energy storage or power capacity or both

is required. Floating vessels may be transferred between one or more installations or projects to, for example, optimize required resources. For example, in some regions, greater electricity storage or power capacity may be required during certain time periods or seasons and / or less electricity storage or power capacity may be required during certain other time periods or seasons. Floating vessels may be transferred to and added to some regions during time periods of greater demand. Floating vessels may be disconnected and / or transferred away during time periods of lesser demand. Floating vessels may be transferred from regions of lesser demand to regions of greater demand as needed. For example, a futures market or spot market or both may be created to lease floating vessels. Floating vessels may be employed as LPG carriers or other forms of carriers when demand for energy storage is low. In some instances, it may be desirable for one or more of the floating vessels and / or the low density liquid and / or a portion of the low density liquid to be leased by the project operator or owner instead of, for example, outright owned.

[0325] Floating vessels may disconnect to avoid severe weather, such as hurricanes. Floating vessels may be disconnected for maintenance. Floating vessels may be updated or replaced over time. For example, new technology advances or application needs or performance needs may be integrated into floating vessels as a retrofit or new floating vessels may be constructed or both. Floating vessels may be disconnected or connected due to changes in demand.

[0326] Floating vessels may exist in multiple forms. For example, a floating vessel may comprise a low density liquid storage unit. For example, a floating vessel may comprise both a low density liquid storage unit and the pump and / or generator. For example, a floating vessel may comprise a pump and / or generator. Floating vessels of multiple forms may be combined or integrated as needed. Floating vessels may be changed or exchanged or integrated differently or possess updated configurations or a combination thereof, which may be simple to conduct in response to, for example, changing needs from one or more application.

[0327] A floating vessel connection buoy may contain an anchor connection or similar device to enable the floating vessel to remain in a general position without or with minimal need for a dynamic positioning system.

[0328] The use of floating vessels may enable practically unlimited energy storage capacity. For example, floating vessels may be interconnected to increase energy storage capacity or power capacity or both. The present embodiment may benefit from the current global capacity to construct and ship large scale floating carriers for LPG and other hydrocarbons and / or the available of floating carriers currently used for, for example, transporting hydrocarbons or offshore floating storage or both.

[0329] The use of floating vessels for the first reservoir and/or pump and / or generator may minimize the permitting and / or approvals required due to, for example, pre-existing permitting for carrier vessels.

[0330] The floating vessels may connect to the buoy by means of a Turret and Swivel Stack, which may be located on the floating vessel. A turret and swivel stack may allow ships to rotate to face the wind or otherwise move while being interconnected a low density liquid pipeline and / or subsea electric cable.

[0331] **Figure 79:** The present figure comprises the embodiment in Figure 78. The present figure shows the present embodiment at a nearly fully charged state.

[0332] **Figure 80:** The present figure comprises the embodiment in Figure 78. The present figure shows the present embodiment discharging or generating electricity.

[0333] **Figure 81:** The present figure comprises the embodiment in Figure 78. The present figure shows the present embodiment at a nearly fully discharged state.

[0334] **Figure 82:** The present figure shows an embodiment where the first reservoir (“1”) and / or pump (“4”) and / or generator (“4”) is located in a floating vessel (“16”). The present figure may show an embodiment where a floating vessel is capable of connecting to a subsea low density liquid pipeline (“3”) and a subsea electrical cable (“15”) by a combined buoy (“LX”). Said combined buoy may be capable of connecting to and / or disconnecting from the floating vessel. Said combined buoy may simplify the connection and / or disconnection process between the floating vessel and the combined buoy. In the present figure, the combined buoy may be shown disconnected from the floating carrier.

[0335] **Figure 83:** The present figure may comprise the same embodiment as Figure 82. In the present figure, the combined buoy may be shown connected to the floating carrier.

[0336] **Figure 84:** An electricity storage system with a surface low density liquid tank (‘1’), an underwater rigid tank (‘2’), a bladder sub-tank configured to store low density liquid (‘10’), and a surface water tank (‘6’).

[0337] The present embodiment at a nearly fully discharged state.

[0338] **Figure 85:** The present embodiment comprises the embodiment in Figure 84.

[0339] The present embodiment storing electricity (‘charging’). Low density liquid is pumped (‘4’) from the surface low density liquid tank (‘1’), through a pipe (‘3’), to the underwater rigid tank (‘2’), displacing water from the underwater rigid tank (‘2’). The displaced water travels through a pipe (‘7’) into surface water tank (‘6’).

[0340] **Figure 86:** The present embodiment comprises the embodiment in Figure 84. The present embodiment at a nearly fully discharged state.

[0341] **Figure 87:** The present embodiment comprises the embodiment in Figure 84.

[0342] An electricity storage system generating electricity ('discharging'). Water in the surface water tank ('6') is transferred through a pipe ('7') into the underwater rigid tank ('2'), where it is allowed to displace low density liquid in the underwater rigid tank ('2'). The displaced low density liquid travels through a pipe ('3'), through a generator ('4'), to the surface tank ('1').

Figure Keys

[0343] **Please note:** Drawing or figures are not drawn to scale.

Figures 39 – 43, 68 Key	
1	A first storage reservoir. A surface storage reservoir. A reservoir at a higher elevation than the second reservoir. A storage tank which is configured to store low density liquid. The storage tank may be rigid, or a bladder tank, or a combination thereof. The storage tank may be pressurized. The low density liquid inside the storage tank may comprise a liquid, a pressurized liquid, a gas-liquid, a liquid and head space gases comprising liquid vapor pressure, or a combination thereof.
2	Second storage reservoir. The second storage reservoir in the present figure may be configured to store low density liquid. The second storage reservoir may possess a pressure inside the storage tank which is near the same as the hydrostatic pressure of the water at the same depth as the second storage reservoir. The second storage reservoir may be buoyant and may float above the ocean floor. The second storage reservoir may be anchored or tethered or both to the ocean floor and may be suspended above the ocean floor. The pressure inside the second storage reservoir may be at equilibrium with the hydrostatic pressure of water at the water depth of the second storage reservoir. In the present figure, '2' may comprise an expandable or collapsible tank, which may comprise, for example, a bladder tank or piston tank or membrane tank or a combination thereof.
3	A pipe, which may comprise a pipeline for transferring low density liquid between the first and second storage reservoirs during storing electricity or 'charging' and during generating electricity or 'discharging'. The pipe may be capable of handling the pressure difference between the low density liquid inside the pipe and the pressure surrounding the pipe. Said pressure difference may be at its maximum near the pump / generator, '4', and at its minimum near the second reservoir, '2'. It may be desirable to optimize the cost of the pipe, by, for example, making the wall thickness and/or maximum pressure capacity of the pipe greater near the surface and less as the pipe approaches the second reservoir. It is important to note the pipe may be located on the sea floor, which is not shown in the present figure.
4	Pump / generator. A pump and / or generator unit. '4' may comprise a Hydraulic Power Recovery Turbine (HPRT), which can reversibly function as both a pump and a generator. '4' may function as the pump and / or generator for the low density liquid.

5	A valve or control system, which may be employed to stop or start or limit or adjust the flow of low density liquid to the generator. Alternatively, or additionally, '5' may comprise an emergency shutoff valve, which may close in the event of a disruption or breach.
Land	Land, which may comprise both land above and below the ocean. Land may comprise a solid.
Ocean	Ocean may comprise liquid water located in the ocean.
Electricity	Electricity may present the flow of electricity to or from the system. If the electricity arrow is pointing toward '4', the system may be storing electricity, by, for example, pumping low density liquid from the first reservoir to the second reservoir. Electricity may be supplied from one or more or a combination of sources, which may include, but are not limited to, an electricity grid, a power generation source, or other sources of electricity. If the electricity arrow is pointing away from '4', the system may be generating or discharging electricity, by, for example, allowing low density liquid from the second reservoir to pass through a generator, generating electricity, and into the first reservoir. Electricity may be supplied to one or more or a combination of applications requiring electricity, which may include, but are not limited to, an electricity grid, a commercial demand, a residential demand, an industrial demand, a transportation demand, or other application for electricity.
C	The dashed lines may represent a label. 'C' may be labeling or representing the tethering or anchoring or mooring or a combination thereof of the second reservoir to the ocean floor. The second reservoir may be buoyant and mechanisms, such as mechanisms represented by 'C', may be employed to suspend the second reservoir above the ocean floor and / or prevent the second reservoir from floating to the ocean surface.
CB	The dashed lines may represent a label. 'CB' may be labeling or representing a containment barrier or cover, which may cover over at least a portion of the second reservoir. Said containment barrier or cover may capture low density liquid or derivatives of low density liquid in the event of a breach or accidental release of low density liquid from the second reservoir. CB may enable the recovery of said low density liquid in the event of a breach.

Figures 44 – 45 Key

6	'6' may represent a rigid tank comprising a third reservoir configured to store water. In Figure 45, the number '6' may be located in the portion of the third reservoir containing water. '6' may alternatively represent a rigid tank configured to store a non-volatile or low volatility liquid or low vapor pressure liquid.
A	'A' and the line surrounding 'A' may comprise a label. 'A' may be a label for a condensed gas, which may be floating on the surface of the water inside the third reservoir. A condensed gas may be at a liquid phase and may be practically insoluble in water. A condensed gas may possess a sufficient vapor pressure to ensure the pressure inside the third reservoir or rigid water tank is close to the pressure outside the third reservoir or rigid water tank. A condensed gas may possess a sufficient vapor pressure to ensure the pressure inside the third reservoir or rigid water tank is greater than or equal to the pressure outside the third reservoir or rigid water tank. A condensed gas may possess a sufficient vapor pressure to ensure the pressure inside the third reservoir or rigid water tank is

	greater than or equal to the pressure outside the third reservoir or rigid water tank while water is emptied from the tank. A condensed gas may be condensable to ensure, for example, the pressure inside the water tank remains relatively consistent while water is added to the tank or while the tank is being filled with water. The pressure inside the tank may remain relatively close to the vapor pressure of the condensable gas at the temperature of the tank.
B	‘B’ and the line surrounding ‘B’ may comprise a label. ‘B’ may be a label for the gas phase of a condensable gas and may comprise the headspace of a rigid water tank or a third reservoir water tank. If a portion of water is added to the tank, ‘B’ may be compressed to a pressure equal to or greater than the vapor pressure of ‘B’, which may result in a portion of ‘B’ condensing on the surface of the water, forming additional condensed gas, or ‘A’. If a portion of water is emptied or removed from the tank, the pressure of ‘B’ may be reduced to equal to or less than the vapor pressure of ‘B’, which may result in a portion of ‘A’ vaporizing or boiling, forming additional ‘B’. The equilibrium between ‘A’ and ‘B’ may be employed to ensure the water tank possesses a relatively consistent internal pressure regardless of whether the water tank is filling with water, emptying of water, or the water tank is at a steady volume of water.

Figures 46 – 53 Key	
1	‘1’ may comprise a first reservoir, which may comprise a reservoir at a higher elevation than a second reservoir. ‘1’ may comprise a tank configured to store a low density liquid. ‘1’ may comprise a pressurized tank, if, for example, the low density liquid possesses a significant vapor pressure or a vapor pressure equal to or greater than the pressure adjacent to the tank.
2	‘2’ may comprise the second storage reservoir. ‘2’ may be located at a lower elevation or at a deeper water depth than the first reservoir. ‘2’ may be configured to store both water and / or low density liquid. ‘2’ may be configured to prevent water from directly contacting low density liquid, while enabling water and low density liquid to exchange pressure. ‘2’ may be configured to prevent water from mixing with low density liquid or prevent low density liquid from dispersing in water or vice versa, while enabling water and low density liquid to exchange pressure. The second reservoir may possess an inside pressure which is near or about the same as the hydrostatic pressure of the water at the same depth as the second storage reservoir.
3	A pipe, which may comprise a pipeline for transferring low density liquid between the first and second storage reservoirs during storing electricity or ‘charging’ and during generating electricity or ‘discharging’. The pipe may be capable of handling the pressure difference between the low density liquid inside the pipe and the pressure surrounding the pipe. Said pressure difference may be at its maximum near the pump / generator, ‘4’, and at its minimum near the second reservoir, ‘2’. It may be desirable to optimize the cost of the pipe, by, for example, making the wall thickness and/or maximum pressure capacity of the pipe greater near the surface and less as the pipe approaches the second reservoir. The pipeline may comprise the same pipeline material or wall thickness or both for the full length of the pipeline if desired. It is important to note the pipe may be located on the sea floor, which is not shown in the present figure. ‘3’ may

	comprise one or more or a combination of pipes. '3' may comprise onshore and / or offshore pipeline. '3' may be located on the seafloor.
4	Pump / generator. A pump and / or generator unit. '4' may comprise a Hydraulic Power Recovery Turbine (HPRT), which can reversibly function as both a pump and a generator. '4' may function as the pump and / or generator for the low density liquid. One or more or a combination of pump / generator units. Low density liquid may comprise the hydraulic fluid in the pump / generator, which may comprise a HPRT unit.
5	A valve or control system, which may be employed to stop or start or limit or adjust the flow of low density liquid to the generator. Alternatively, or additionally, '5' may comprise an emergency shutoff valve, which may close in the event of a disruption or breach.
8	A third reservoir which stores water. In the present embodiment, the third reservoir may comprise an external water tank which possesses an internal pressure near the pressure water at the depth of the external water tank and / or second reservoir. The external water reservoir may comprise a bladder tank or a floating bladder tank. The external water tank may be interconnected to the second reservoir via a pipe. The third reservoir may store water displaced by low density liquid during charging and provide water to displace low density liquid during discharging.
9	A water pipe. '9' may comprise a water pipe which interconnect the external water reservoir, '8', to the second reservoir.
Land	Land, which may comprise both land above and below the ocean. Land may comprise a solid.
Ocean	Ocean may comprise liquid water located in the ocean.
Electricity	Electricity may present the flow of electricity to or from the system. If the electricity arrow is pointing toward '4', the system may be storing electricity, by, for example, pumping low density liquid from the first reservoir to the second reservoir. Electricity may be supplied from one or more or a combination of sources, which may include, but are not limited to, an electricity grid, a power generation source, or other sources of electricity. If the electricity arrow is pointing away from '4', the system may be generating or discharging electricity, by, for example, allowing low density liquid from the second reservoir to pass through a generator, generating electricity, and into the first reservoir. Electricity may be supplied to one or more or a combination of applications requiring electricity, which may include, but are not limited to, an electricity grid, a commercial demand, a residential demand, an industrial demand, a transportation demand, or other application for electricity.
S	'S' and the dashed lines may comprise a label. 'S' may label a separator or physical barrier which may prevent or minimize the mixing or direct contact or both between low density liquid and water in the second reservoir. 'S' may comprise a solid or a liquid. 'S' may comprise a medium with a density greater than low density liquid and less than water. 'S' may comprise a flexible solid. 'S' may comprise a floating barrier. 'S' may comprise a fabric or liner. 'S' may comprise low density liquid – water hydrates, which may be a solid. 'S' may comprise a piston. 'S' may possess a density greater than both water and low density liquid and / or may comprise a component attached internally to a rigid tank comprising the second reservoir. 'S' may comprise an internal sub-tank,

	which may be located inside a rigid tank and may be employed to store low density liquid or water or both.
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Figures 54 – 57, 69, 84 – 87 Key	
1	‘1’ may comprise a first reservoir, which may comprise a reservoir at a higher elevation than a second reservoir. ‘1’ may comprise a tank configured to store a low density liquid. ‘1’ may comprise a pressurized tank, if, for example, the low density liquid possesses a significant vapor pressure or a vapor pressure equal to or greater than the pressure adjacent to the tank.
2	‘2’ may comprise the second storage reservoir. ‘2’ may be located at a lower elevation or at a deeper water depth than the first reservoir. ‘2’ may be configured to store both water and / or low density liquid. ‘2’ may be configured to prevent water from directly contacting low density liquid, while enabling water and low density liquid to exchange pressure. ‘2’ may be configured to prevent water from mixing with low density liquid or prevent low density liquid from dispersing in water or vice versa, while enabling water and low density liquid to exchange pressure. The second reservoir may possess an inside pressure which is near or about the same as the hydrostatic pressure of the water at the same depth as the second storage reservoir. The second storage reservoir may be rigid in construction. In the present figure, the low density liquid and / or water inside the second storage reservoir may be mechanically isolated from the ocean water adjacent to or outside the second storage reservoir.
3	A pipe, which may comprise a pipeline for transferring low density liquid between the first and second storage reservoirs during storing electricity or ‘charging’ and during generating electricity or ‘discharging’. The pipe may be capable of handling the pressure difference between the low density liquid inside the pipe and the pressure surrounding the pipe. Said pressure difference may be at its maximum near the pump / generator, ‘4’, and at its minimum near the second reservoir, ‘2’. It may be desirable to optimize the cost of the pipe, by, for example, making the wall thickness and/or maximum pressure capacity of the pipe greater near the surface and less as the pipe approaches the second reservoir. It is important to note the pipe may be located on the sea floor, which is not shown in the present figure. ‘3’ may comprise one or more or a combination of pipes. ‘3’ may comprise onshore and / or offshore pipeline. ‘3’ may be located on the seafloor.
4	Pump / generator. A pump and / or generator unit. ‘4’ may comprise a Hydraulic Power Recovery Turbine (HPRT), which can reversibly function as both a pump and a generator. ‘4’ may function as the pump and / or generator for the low density liquid. One or more or a combination of pump / generator units. Low density liquid may comprise the hydraulic fluid in the pump / generator, which may comprise a HPRT unit.
5	A valve or control system, which may be employed to stop or start or limit or adjust the flow of low density liquid to the generator. Alternatively, or additionally, ‘5’ may comprise an emergency shutoff valve, which may close in the event of a disruption or breach.
6	A third reservoir. In the present figure, the third reservoir may be located on the surface or on the ocean or above the ocean or on land or at a higher elevation than the second reservoir or a combination thereof. In the present embodiment,

	the third reservoir may comprise a bladder tank or a rigid tank or a combination thereof. In the present figure, the third reservoir may comprise a rigid tank. In the present figure, the third reservoir may be configured similar to the embodiment shown in Figures 44 and 45. The pressure inside the third reservoir in the present figure may be near or equal to the pressure outside the third reservoir or the pressure inside the third reservoir may be within 5 atm or within 10 atm of the pressure outside the third reservoir.
7	A pipe, which may comprise a pipeline for transferring water between the first and third storage reservoirs during storing electricity or ‘charging’ and during generating electricity or ‘discharging’. The water in the pipe may comprise a similar density or the same density as the ocean water outside the pipe, which may enable a minimal pressure difference between the inside and outside of the pipe and may reduce pipe material cost. It is important to note the pipe may be located on the sea floor, which is not shown in the present figure. ‘7’ may comprise one or more or a combination of pipes. ‘7’ may comprise onshore and / or offshore pipeline. ‘7’ may be located on the seafloor.
Land	Land, which may comprise both land above and below the ocean. Land may comprise a solid.
Ocean	Ocean may comprise liquid water located in the ocean.
Electricity	Electricity may present the flow of electricity to or from the system. If the electricity arrow is pointing toward ‘4’, the system may be storing electricity, by, for example, pumping low density liquid from the first reservoir to the second reservoir. Electricity may be supplied from one or more or a combination of sources, which may include, but are not limited to, an electricity grid, a power generation source, or other sources of electricity. If the electricity arrow is pointing away from ‘4’, the system may be generating or discharging electricity, by, for example, allowing low density liquid from the second reservoir to pass through a generator, generating electricity, and into the first reservoir. Electricity may be supplied to one or more or a combination of applications requiring electricity, which may include, but are not limited to, an electricity grid, a commercial demand, a residential demand, an industrial demand, a transportation demand, or other application for electricity.
CB	The dashed lines may represent a label. ‘CB’ may be labeling or representing a containment barrier or cover, which may cover over at least a portion of the second reservoir. Said containment barrier or cover may capture low density liquid or derivatives of low density liquid in the event of a breach or accidental release of low density liquid from the second reservoir. CB may enable the recovery of said low density liquid in the event of a breach.

Figures 58 – 61, 67 Key	
1	‘1’ may comprise a first reservoir, which may comprise a reservoir at a higher elevation than a second reservoir. ‘1’ may comprise a tank configured to store a low density liquid. ‘1’ may comprise a pressurized tank, if, for example, the low density liquid possesses a significant vapor pressure or a vapor pressure equal to or greater than the pressure adjacent to the tank.
2	‘2’ may comprise the second storage reservoir. ‘2’ may be located at a lower elevation or at a deeper water depth than the first reservoir. ‘2’ may be configured to store both water and / or low density liquid. ‘2’ may be configured

	to prevent water from directly contacting low density liquid, while enabling water and low density liquid to exchange pressure. '2' may be configured to prevent water from mixing with low density liquid or prevent low density liquid from dispersing in water or vice versa, while enabling water and low density liquid to exchange pressure. A sub-tank may be located inside '2' which stores low density liquid or water. In the present figure, the sub-tank stores low density liquid. The sub-tank may comprise a membrane or flexible liner. The sub-tank may comprise a bladder tank, which may be entirely contained within the rigid tank. The sub-tank may be attached to the inside walls of a rigid tank. The sub-tank may be connected to directly to the low density liquid pipe, '3', and / or directly connected to the inside or outside walls of the rigid tank. The second reservoir may possess an inside pressure which is near or about the same as the hydrostatic pressure of the water at the same depth as the second storage reservoir.
3	A pipe, which may comprise a pipeline for transferring low density liquid between the first and second storage reservoirs during storing electricity or 'charging' and during generating electricity or 'discharging'. The pipe may be capable of handling the pressure difference between the low density liquid inside the pipe and the pressure surrounding the pipe. Said pressure difference may be at its maximum near the pump / generator, '4', and at its minimum near the second reservoir, '2'. It may be desirable to optimize the cost of the pipe, by, for example, making the wall thickness and/or maximum pressure capacity of the pipe greater near the surface and less as the pipe approaches the second reservoir. The pipeline may comprise the same pipeline material or wall thickness or both for the full length of the pipeline if desired. It is important to note the pipe may be located on the sea floor, which is not shown in the present figure. '3' may comprise one or more or a combination of pipes. '3' may comprise onshore and / or offshore pipeline. '3' may be located on the seafloor.
4	Pump / generator. A pump and / or generator unit. '4' may comprise a Hydraulic Power Recovery Turbine (HPRT), which can reversibly function as both a pump and a generator. '4' may function as the pump and / or generator for the low density liquid. One or more or a combination of pump / generator units. Low density liquid may comprise the hydraulic fluid in the pump / generator, which may comprise a HPRT unit.
5	A valve or control system, which may be employed to stop or start or limit or adjust the flow of low density liquid to the generator. Alternatively, or additionally, '5' may comprise an emergency shutoff valve, which may close in the event of a disruption or breach.
8	A third reservoir which stores water. In the present embodiment, the third reservoir may comprise an external water tank which possesses an internal pressure near the pressure water at the depth of the external water tank and / or second reservoir. The external water reservoir may comprise a bladder tank or a floating bladder tank. The external water tank may be interconnected to the second reservoir via a pipe. The third reservoir may store water displaced by low density liquid during charging and provide water to displace low density liquid during discharging.
9	A water pipe. '9' may comprise a water pipe which interconnect the external water reservoir, '8', to the second reservoir.

10	A subtank, which may be located on the inside of the second reservoir or the second reservoir comprising a rigid tank. '10' may be directly connected to the low density liquid pipeline, '3', and / or may be directly connected to the internal and / or external wall of the second reservoir or the second reservoir comprising a rigid tank. '10' may comprise a sub-tank for storing low density liquid within the second reservoir. '10' may be configured such that if there were a breach in '10', low density liquid would be contained within the internal walls of the second reservoir. '10' may be configured such that if there were a breach in '8', low density liquid would remain in the second storage reservoir and the system may continue operability. Said subtank may comprise liner or membrane. Said subtank may comprise a bladder tank, or a piston tank, or an expandable or collapsible tank or a combination thereof.
Land	Land, which may comprise both land above and below the ocean. Land may comprise a solid.
Ocean	Ocean may comprise liquid water located in the ocean.
Electricity	Electricity may present the flow of electricity to or from the system. If the electricity arrow is pointing toward '4', the system may be storing electricity, by, for example, pumping low density liquid from the first reservoir to the second reservoir. Electricity may be supplied from one or more or a combination of sources, which may include, but are not limited to, an electricity grid, a power generation source, or other sources of electricity. If the electricity arrow is pointing away from '4', the system may be generating or discharging electricity, by, for example, allowing low density liquid from the second reservoir to pass through a generator, generating electricity, and into the first reservoir. Electricity may be supplied to one or more or a combination of applications requiring electricity, which may include, but are not limited to, an electricity grid, a commercial demand, a residential demand, an industrial demand, a transportation demand, or other application for electricity.
CB	The dashed lines may represent a label. 'CB' may be labeling or representing a containment barrier or cover, which may cover over at least a portion of the second reservoir. Said containment barrier or cover may capture low density liquid or derivatives of low density liquid in the event of a breach or accidental release of low density liquid from the second reservoir. CB may enable the recovery of said low density liquid in the event of a breach.

Figures 62 – 66 Key

1	'1' may comprise a first reservoir, which may comprise a reservoir at a higher elevation than a second reservoir. '1' may comprise a tank configured to store a low density liquid. '1' may comprise a pressurized tank, if, for example, the low density liquid possesses a significant vapor pressure or a vapor pressure equal to or greater than the pressure adjacent to the tank.
2	'2' may comprise the second storage reservoir. '2' may be located at a lower elevation or at a deeper water depth than the first reservoir. '2' may be configured to store both water and / or low density liquid. '2' may be configured to prevent water from directly contacting low density liquid, while enabling water and low density liquid to exchange pressure. '2' may be configured to prevent water from mixing with low density liquid or prevent low density liquid from dispersing in water or vice versa, while enabling water and low density

	liquid to exchange pressure. A sub-tank may be located inside '2' which stores low density liquid. In the present figure, the sub-tank stores low density liquid. The sub-tank may comprise a membrane or flexible liner. The sub-tank may comprise a bladder tank, which may be entirely contained within the rigid tank. The sub-tank may be attached to the inside walls of a rigid tank. The sub-tank may be connected directly to the low density liquid pipe, '3', and / or directly connected to the inside or outside walls of the rigid tank. The embodiment may employ a second reservoir which is interconnected directly or in fluid communication with open ocean. For example, the present embodiment may involve a second reservoir with a port or pipe or a combination thereof open to the ocean. Said port or pipe may contain a flow control mechanism, such as a valve, which may close or narrow or open or a combination thereof if desired. Said flow control mechanism may enable the second storage reservoir to close or isolate its internal contents in the event of or before, for example, a breach of the sub-tank ('10') or adverse environment or surrounding conditions or as a preventative measure. In the present embodiment, the open ocean may be considered the 'third reservoir'. The second reservoir may contain sensors or other mechanisms for detecting a leak or breach of the sub-tank or rigid tank or an accidental release or leak or breach of low density liquid. The second reservoir may contain mechanisms for containing or preventing release of low density liquid, which may be activated or initiated passively or automatically or with input from an operator or a combination thereof. Deep ocean water may contain low dissolved oxygen concentration levels, which may prevent or minimize corrosion or biofouling or scaling on one or more components or system inside or connected to the second reservoir. The second reservoir may possess an inside pressure which is near or about the same as the hydrostatic pressure of the water at the same depth as the second storage reservoir.
3	A pipe, which may comprise a pipeline for transferring low density liquid between the first and second storage reservoirs during storing electricity or 'charging' and during generating electricity or 'discharging'. The pipe may be capable of handling the pressure difference between the low density liquid inside the pipe and the pressure surrounding the pipe. Said pressure difference may be at its maximum near the pump / generator, '4', and at its minimum near the second reservoir, '2'. It may be desirable to optimize the cost of the pipe, by, for example, making the wall thickness and/or maximum pressure capacity of the pipe greater near the surface and less as the pipe approaches the second reservoir. The pipeline may comprise the same pipeline material or wall thickness or both for the full length of the pipeline if desired. It is important to note the pipe may be located on the sea floor, which is not shown in the present figure. '3' may comprise one or more or a combination of pipes. '3' may comprise onshore and / or offshore pipeline. '3' may be located on the seafloor.
4	Pump / generator. A pump and / or generator unit. '4' may comprise a Hydraulic Power Recovery Turbine (HPRT), which can reversibly function as

	both a pump and a generator. '4' may function as the pump and / or generator for the low density liquid. One or more or a combination of pump / generator units. Low density liquid may comprise the hydraulic fluid in the pump / generator, which may comprise a HPRT unit.
5	A valve or control system, which may be employed to stop or start or limit or adjust the flow of low density liquid to the generator. Alternatively, or additionally, '5' may comprise an emergency shutoff valve, which may close in the event of a disruption or breach.
11	A pipe or port or a combination thereof which enables transfer of ocean water between, for example, the inside and outside of the second storage reservoir. '11' may contain one or more or a combination of fluid control mechanisms, such as valves, or flow meters, or flow rate controllers. One of the openings of '11' may be located near the bottom of the second reservoir to, for example, prevent low density liquid from entering '11' in the event of an accidental release or breach of the subtank within the second reservoir.
Land	Land, which may comprise both land above and below the ocean. Land may comprise a solid.
Ocean	Ocean may comprise liquid water located in the ocean.
Electricity	Electricity may present the flow of electricity to or from the system. If the electricity arrow is pointing toward '4', the system may be storing electricity, by, for example, pumping low density liquid from the first reservoir to the second reservoir. Electricity may be supplied from one or more or a combination of sources, which may include, but are not limited to, an electricity grid, a power generation source, or other sources of electricity. If the electricity arrow is pointing away from '4', the system may be generating or discharging electricity, by, for example, allowing low density liquid from the second reservoir to pass through a generator, generating electricity, and into the first reservoir. Electricity may be supplied to one or more or a combination of applications requiring electricity, which may include, but are not limited to, an electricity grid, a commercial demand, a residential demand, an industrial demand, a transportation demand, or other application for electricity.
CB	The dashed lines may represent a label. 'CB' may be labeling or representing a containment barrier or cover, which may cover over at least a portion of the second reservoir. Said containment barrier or cover may capture low density liquid or derivatives of low density liquid in the event of a breach or accidental release of low density liquid from the second reservoir. CB may enable the recovery of said low density liquid in the event of a breach.

Figures 70 – 73 Key

1	'1' may comprise a first reservoir, which may comprise a reservoir at a higher elevation than a second reservoir. '1' may comprise a tank configured to store a low density liquid. '1' may comprise a pressurized tank, if, for example, the low density liquid possesses a significant vapor pressure or a vapor pressure equal to or greater than the pressure adjacent to the tank.
2	Second reservoir which may be configured to contain water and low density liquid. A rigid structure. May comprise a tank. May comprise a rigid tank with an opening or port or pipe or a combination thereof interconnected with the ocean. May comprise a compartment or concave structure or containment

	structure. The second reservoir may be configured to store water and low density liquid. The second reservoir may be configured to comprise a subtank configured to store low density liquid. Said subtank may be water tight. Said subtank may be directly connected to the low density liquid pipe ('3'). The second reservoir may be configured to contain or prevent release of low density liquid into the surrounding ocean in the event of, for example, a breach of the subtank or release of low density liquid or a combination thereof.
3	A pipe, which may comprise a pipeline for transferring low density liquid between the first and second storage reservoirs during storing electricity or 'charging' and during generating electricity or 'discharging'. The pipe may be capable of handling the pressure difference between the low density liquid inside the pipe and the pressure surrounding the pipe. Said pressure difference may be at its maximum near the pump / generator, '4', and at its minimum near the second reservoir, '2'. It may be desirable to optimize the cost of the pipe, by, for example, making the wall thickness and/or maximum pressure capacity of the pipe greater near the surface and less as the pipe approaches the second reservoir. The pipeline may comprise the same pipeline material or wall thickness or both for the full length of the pipeline if desired. '3' may comprise one or more or a combination of pipes. '3' may comprise onshore and / or offshore pipeline.
4	Pump / generator. A pump and / or generator unit. '4' may comprise a Hydraulic Power Recovery Turbine (HPRT), which can reversibly function as both a pump and a generator. '4' may function as the pump and / or generator for the low density liquid. One or more or a combination of pump / generator units. Low density liquid may comprise the hydraulic fluid in the pump / generator, which may comprise a HPRT unit.
5	A subtank, which may be located on the inside of the second reservoir or the second reservoir comprising a rigid tank. '5' may be directly connected to the low density liquid pipeline, '3', and / or may be directly connected to the internal and / or external wall of the second reservoir or the second reservoir comprising a rigid tank. '5' may comprise a sub-tank for storing low density liquid within the second reservoir. '5' may be configured such that if there were a breach in '5', low density liquid would be contained within the internal walls of the second reservoir. Said subtank may comprise liner or membrane. Said subtank may comprise a bladder tank, or a piston tank, or an expandable or collapsible tank or a combination thereof.
Land	Land, which may comprise both land above and below the ocean. Land may comprise a solid.
Ocean	Ocean may comprise liquid water located in the ocean.
Electricity	Electricity may present the flow of electricity to or from the system. If the electricity arrow is pointing toward '4', the system may be storing electricity, by, for example, pumping low density liquid from the first reservoir to the second reservoir. Electricity may be supplied from one or more or a combination of sources, which may include, but are not limited to, an electricity grid, a power generation source, or other sources of electricity. If the electricity arrow is pointing away from '4', the system may be generating or discharging electricity, by, for example, allowing low density liquid from the second reservoir to pass through a generator, generating electricity, and into the first reservoir. Electricity may be supplied to one or more or a combination of applications requiring electricity, which may include, but are not limited to, an electricity grid, a

	commercial demand, a residential demand, an industrial demand, a transportation demand, or other application for electricity.
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Figures 74 – 77 Key	
1	‘1’ may comprise a first reservoir, which may comprise a reservoir at a higher elevation than a second reservoir. ‘1’ may comprise a tank configured to store a low density liquid. In the present figure, the first reservoir may be located underwater. The first reservoir may be a rigid tank. The low density liquid in the first reservoir may possess a vapor pressure about the same as the hydrostatic pressure of the water at the same depth of the first reservoir at the temperature of the low density liquid and / or the temperature of the water at the same depth as the first reservoir. The vapor pressure may be within 10 atm of the pressure of the hydrostatic pressure of the water at the depth of the first reservoir. The underwater depth of the first reservoir may be sufficiently deep to ensure the first reservoir allows boat traffic (if any) travel above it. The underwater depth of the first reservoir may be sufficiently deep to prevent or minimize the presence of ocean currents, ocean waves, or other potentially damaging elements. The underwater depth of the first reservoir may be sufficiently deep to ensure the temperature surrounding the tank is consistently below a certain temperature range to, for example, ensure the vapor pressure of the low-density liquid is below a pre-designed pressure range. The first reservoir may comprise a bladder tank. The first reservoir may possess about the same pressure inside the tank as the hydrostatic of water at the same ocean water depth or a vapor pressure less than the hydrostatic of water at the same ocean water depth.
2	‘2’ may comprise the second storage reservoir. ‘2’ may be located at a lower elevation or at a deeper water depth than the first reservoir. ‘2’ may be configured to store both water and / or low density liquid. ‘2’ may be configured to prevent water from directly contacting low density liquid, while enabling water and low density liquid to exchange pressure. ‘2’ may be configured to prevent water from mixing with low density liquid or prevent low density liquid from dispersing in water or vice versa, while enabling water and low density liquid to exchange pressure. A sub-tank may be located inside ‘2’ which stores low density liquid. In the present figure, the sub-tank stores low density liquid. The sub-tank may comprise a membrane or flexible liner. The sub-tank may comprise a bladder tank, which may be entirely contained within the rigid tank. The sub-tank may be attached to the inside walls of a rigid tank. The sub-tank may be connected to directly to the low density liquid pipe, ‘3’, and / or directly connected to the inside or outside walls of the rigid tank. The embodiment may employ a second reservoir which is interconnected directly or in fluid communication with open ocean. For example, the present embodiment may involve a second reservoir with a port or pipe or a combination

	thereof open to the ocean. Said port or pipe may contain a flow control mechanism, such as a valve, which may close or narrow or open or a combination thereof if desired. Said flow control mechanism may enable the second storage reservoir to close or isolate its internal contents in the event of or before, for example, a breach of the subtank ('5') or adverse environment or surrounding conditions or as a preventative measure. In the present embodiment, the open ocean may be considered the 'third reservoir'. The second reservoir may contain sensors or other mechanisms for detecting a leak or breach of the subtank or rigid tank or an accidental release or leak or breach of low density liquid. The second reservoir may contain mechanisms for containing or preventing release of low density liquid, which may be activated or initiated passively or automatically or with input from an operator or a combination thereof. Deep ocean water may contain low dissolved oxygen concentration levels, which may prevent or minimize corrosion or biofouling or scaling on one or more components or system inside or connected to the second reservoir. The second reservoir may possess an inside pressure which is near or about the same as the hydrostatic pressure of the water at the same depth as the second storage reservoir. Note the dashed lines represent a label.
3	A pipe, which may comprise a pipeline for transferring low density liquid between the first and second storage reservoirs during storing electricity or 'charging' and during generating electricity or 'discharging'. The pipe may be capable of handling the pressure difference between the low density liquid inside the pipe and the pressure surrounding the pipe. Said pressure difference may be at its maximum near the pump / generator, '4', and at its minimum near the second reservoir, '2'. It may be desirable to optimize the cost of the pipe, by, for example, making the wall thickness and/or maximum pressure capacity of the pipe greater near the surface and less as the pipe approaches the second reservoir. The pipeline may comprise the same pipeline material or wall thickness or both for the full length of the pipeline if desired. '3' may comprise one or more or a combination of pipes. In the present embodiment, '3' may comprise an entirely offshore pipeline. Note the dashed lines represent a label.
4	Pump / generator. A pump and / or generator unit. '4' may comprise a Hydraulic Power Recovery Turbine (HPRT), which can reversibly function as both a pump and a generator. '4' may function as the pump and / or generator for the low density liquid. One or more or a combination of pump / generator units. Low density liquid may comprise the hydraulic fluid in the pump / generator. In the present embodiment, '4' may be configured to operate underwater.
5	A subtank, which may be located on the inside of the second reservoir or the second reservoir comprising a rigid tank. '5' may be directly connected to the low density liquid pipeline, '3', and / or may be directly connected to the internal

	and / or external wall of the second reservoir or the second reservoir comprising a rigid tank. '5' may comprise a sub-tank for storing low density liquid within the second reservoir. '5' may be configured such that if there were a breach in '5', low density liquid would be contained within the internal walls of the second reservoir. Said subtank may comprise liner or membrane. Said subtank may comprise a bladder tank, or a piston tank, or an expandable or collapsible tank or a combination thereof.
13	A power source or a power demand source or both. For example, '13' may comprise an electricity grid or an interconnection to an electricity grid or a combination thereof.
14	A power transmission station or power handling site. '14' may comprise a control station or power control station or a combination thereof. '14' may comprise a power interconnection between a subsea power cable and on-land power infrastructure.
15	A subsea electric power transmission cable. The subsea cable may transfer electricity to and from the pump / generator or first reservoir. The subsea cable may transfer electricity from one or more electricity sources, such as on-shore and / or offshore power sources, to the energy storage system. The subsea cable may transfer electricity from the energy storage system to one or more applications requiring electricity, which may be located onshore or offshore. Note the dashed lines represent a label.
Land	Land may comprise land, which may be above water or below water. The land may exist at various water depths and with various topographies.
Ocean	Ocean may comprise liquid water located in the ocean.
E	'E' may represent electricity. Electricity may present the flow of electricity to or from the system. Electricity may be supplied from one or more or a combination of sources, which may include, but are not limited to, an electricity grid, a power generation source, or other sources of electricity. Electricity may be supplied to one or more or a combination of applications requiring electricity, which may include, but are not limited to, an electricity grid, a commercial demand, a residential demand, an industrial demand, a transportation demand, or other application for electricity.

Figures 78 – 83 Key

1	'1' may comprise a first reservoir, which may comprise a reservoir at a higher elevation than a second reservoir. '1' may comprise a tank configured to store a low density liquid. In the present figure, the first reservoir may be located on or in a floating vessel ('16'). The first reservoir may be configured similar to hydrocarbons storage or butane storage or LPG storage or propane storage or other low density liquids storage on ships. The first reservoir may be interconnected to a pump and / or generator ('4'), which may be co-located on a floating vessel or on the same floating vessel or underwater or a combination thereof.
2	'2' may comprise the second storage reservoir. '2' may be located at a lower elevation or at a deeper water depth than the first reservoir. '2' may be configured to store both water and / or low density liquid. '2' may be configured

	to prevent water from directly contacting low density liquid, while enabling water and low density liquid to exchange pressure. '2' may be configured to prevent water from mixing with low density liquid or prevent low density liquid from dispersing in water or vice versa, while enabling water and low density liquid to exchange pressure. A sub-tank may be located inside '2' which stores low density liquid. In the present figure, the sub-tank stores low density liquid. The sub-tank may comprise a membrane or flexible liner. The sub-tank may comprise a bladder tank, which may be entirely contained within the rigid tank. The sub-tank may be attached to the inside walls of a rigid tank. The sub-tank may be connected directly to the low density liquid pipe, '3', and / or directly connected to the inside or outside walls of the rigid tank. The embodiment may employ a second reservoir which is interconnected directly or in fluid communication with open ocean. For example, the present embodiment may involve a second reservoir with a port or pipe or a combination thereof open to the ocean. Said port or pipe may contain a flow control mechanism, such as a valve, which may close or narrow or open or a combination thereof if desired. Said flow control mechanism may enable the second storage reservoir to close or isolate its internal contents in the event of or before, for example, a breach of the sub-tank ('5') or adverse environment or surrounding conditions or as a preventative measure. In the present embodiment, the open ocean may be considered the 'third reservoir'. The second reservoir may contain sensors or other mechanisms for detecting a leak or breach of the sub-tank or rigid tank or an accidental release or leak or breach of low density liquid. The second reservoir may contain mechanisms for containing or preventing release of low density liquid, which may be activated or initiated passively or automatically or with input from an operator or a combination thereof. Deep ocean water may contain low dissolved oxygen concentration levels, which may prevent or minimize corrosion or biofouling or scaling on one or more components or system inside or connected to the second reservoir. The second reservoir may possess an inside pressure which is near or about the same as the hydrostatic pressure of the water at the same depth as the second storage reservoir. Note the dashed lines represent a label.
3	A pipe, which may comprise a pipeline for transferring low density liquid between the first and second storage reservoirs during storing electricity or 'charging' and during generating electricity or 'discharging'. The pipe may be capable of handling the pressure difference between the low density liquid inside the pipe and the pressure surrounding the pipe. Said pressure difference may be at its maximum near the pump / generator, '4', and at its minimum near the second reservoir, '2'. '3' may include flow risers and / or an interconnected buoy ('L' or 'LX') to enable connection of '3' to the pump / generator ('4') and the first reservoir ('1')

	on a floating vessel ('16'). '3' may interconnect low density liquid in the second reservoir with a surface buoy and / or with a floating vessel comprising a first storage reservoir.
4	Pump / generator. A pump and / or generator unit. '4' may comprise a Hydraulic Power Recovery Turbine (HPRT), which can reversibly function as both a pump and a generator. '4' may function as the pump and / or generator for the low density liquid. One or more or a combination of pump / generator units. Low density liquid may comprise the hydraulic fluid in the pump / generator. In the present embodiment, '4' may be located on a floating vessel.
5	A subtank, which may be located on the inside of the second reservoir or the second reservoir comprising a rigid tank. '5' may be directly connected to the low density liquid pipeline, '3', and / or may be directly connected to the internal and / or external wall of the second reservoir or the second reservoir comprising a rigid tank. '5' may comprise a sub-tank for storing low density liquid within the second reservoir. '5' may be configured such that if there were a breach in '5', low density liquid would be contained within the internal walls of the second reservoir. Said subtank may comprise liner or membrane. Said subtank may comprise a bladder tank, or a piston tank, or an expandable or collapsible tank or a combination thereof.
13	A power source or a power demand source or both. For example, '13' may comprise an electricity grid or an interconnection to an electricity grid or a combination thereof.
14	A power transmission station or power handling site. '14' may comprise a control station or power control station or a combination thereof. '14' may comprise a power interconnection between a subsea power cable and on-land power infrastructure.
15	A subsea electric power transmission cable. The subsea cable may transfer electricity to and from the pump / generator or first reservoir. The subsea cable may transfer electricity from one or more electricity sources, such as on-shore and / or offshore power sources, to the energy storage system. The subsea cable may transfer electricity from the energy storage system to one or more applications requiring electricity, which may be located onshore or offshore. '15' may include flow risers and / or an interconnected buoy ('X' or 'LX') to enable connection of '15' to the pump / generator ('4') on a floating vessel ('16'). Note the dashed lines represent a label.
16	A floating vessel comprising a first reservoir ('1') and / or a pump / generator ('4'). The pump and / or generator may be configured to pump low density liquid and / or convert the hydraulic power of the low density liquid into electricity. '16' may also comprise a connection and / or disconnection system to connect 'L' or 'X' or 'LX' and / or interconnect the low density liquid and electricity to the appropriate areas of '4'. '16' may comprise a carrier ship or hydrocarbon carrier ship or a LPG carrier or a butane carrier or a hydrocarbon carrier or a retrofitted ship or a custom designed ship or a combination thereof.

Land	Land may comprise land, which may be above water or below water. The land may exist at various water depths and with various topographies.
Ocean	Ocean may comprise liquid water located in the ocean.
E	‘E’ may represent electricity. Electricity may present the flow of electricity to or from the system. Electricity may be supplied from one or more or a combination of sources, which may include, but are not limited to, an electricity grid, a power generation source, or other sources of electricity. Electricity may be supplied to one or more or a combination of applications requiring electricity, which may include, but are not limited to, an electricity grid, a commercial demand, a residential demand, an industrial demand, a transportation demand, or other application for electricity.
L	‘L’ may comprise a disconnectable buoy designed for the interconnection of a low density liquid pipeline to a floating vessel. ‘L’ may comprise flow control and flow interconnection mechanisms to enable, for example, connection and / or disconnection with a floating vessel.
X	‘X’ may comprise a disconnectable buoy designed for the interconnection of a subsea power cable with a pump and / or generator located on a floating vessel. ‘X’ may comprise flow control and flow interconnection mechanisms to enable, for example, connection and / or disconnection with a floating vessel.
LX	‘LX’ may comprise a disconnectable buoy designed to enable the interconnection of a low density liquid pipeline to a floating vessel and the interconnection of a subsea cable to a floating vessel. ‘LX’ may comprise a combined buoy in which both an interconnection system for a low density liquid pipeline and an interconnection system for a subsea power cable are located. ‘LX’ may comprise flow control and flow interconnection mechanisms to enable, for example, connection and / or disconnection with a floating vessel.

Figures 84 – 87 Key	
1	‘1’ may comprise a first reservoir, which may comprise a reservoir at a higher elevation than a second reservoir. ‘1’ may comprise a tank configured to store a low density liquid. ‘1’ may comprise a pressurized tank, if, for example, the low density liquid possesses a significant vapor pressure or a vapor pressure equal to or greater than the pressure adjacent to the tank.
2	‘2’ may comprise the second storage reservoir. ‘2’ may be located at a lower elevation or at a deeper water depth than the first reservoir. ‘2’ may be configured to store both water and / or low density liquid. ‘2’ may be configured to prevent water from directly contacting low density liquid, while enabling water and low density liquid to exchange pressure. ‘2’ may be configured to prevent water from mixing with low density liquid or prevent low density liquid from dispersing in water or vice versa, while enabling water and low density liquid to exchange pressure. A sub-tank may be located inside ‘2’ which stores low density liquid or water. In the present figure, the sub-tank stores low density liquid. The sub-tank may comprise a membrane or flexible liner. The sub-tank may comprise a bladder tank, which may be entirely contained within the rigid tank. The sub-tank may be attached to the inside walls of a rigid tank. The sub-tank may be connected to directly to the low density liquid pipe, ‘3’, and / or directly connected to the inside or outside walls of the rigid tank.

	The second reservoir may possess an inside pressure which is near or about the same as the hydrostatic pressure of the water at the same depth as the second storage reservoir. The second reservoir in the present embodiment may be mechanically isolated from the ocean at the water depth of the second reservoir.
3	A pipe, which may comprise a pipeline for transferring low density liquid between the first and second storage reservoirs during storing electricity or ‘charging’ and during generating electricity or ‘discharging’. The pipe may be capable of handling the pressure difference between the low density liquid inside the pipe and the pressure surrounding the pipe. Said pressure difference may be at its maximum near the pump / generator, ‘4’, and at its minimum near the second reservoir, ‘2’. It may be desirable to optimize the cost of the pipe, by, for example, making the wall thickness and/or maximum pressure capacity of the pipe greater near the surface and less as the pipe approaches the second reservoir. The pipeline may comprise the same pipeline material or wall thickness or both for the full length of the pipeline if desired. It is important to note the pipe may be located on the sea floor, which is not shown in the present figure. ‘3’ may comprise one or more or a combination of pipes. ‘3’ may comprise onshore and / or offshore pipeline. ‘3’ may be located on the seafloor.
4	Pump / generator. A pump and / or generator unit. ‘4’ may comprise a Hydraulic Power Recovery Turbine (HPRT), which can reversibly function as both a pump and a generator. ‘4’ may function as the pump and / or generator for the low density liquid. One or more or a combination of pump / generator units. Low density liquid may comprise the hydraulic fluid in the pump / generator, which may comprise a HPRT unit.
5	A valve or control system, which may be employed to stop or start or limit or adjust the flow of low density liquid to the generator. Alternatively, or additionally, ‘5’ may comprise an emergency shutoff valve, which may close in the event of a disruption or breach.
6	A third reservoir. In the present figure, the third reservoir may be located on the surface or on the ocean or above the ocean or on land or at a higher elevation than the second reservoir or a combination thereof. In the present embodiment, the third reservoir may comprise a bladder tank or a rigid tank or a combination thereof. In the present figure, the third reservoir may comprise a rigid tank. In the present figure, the third reservoir may be configured similar to the embodiment shown in Figures 44 and 45. The pressure inside the third reservoir in the present figure may be near or equal to the pressure outside the third reservoir or the pressure inside the third reservoir may be within 5 atm or within 10 atm of the pressure outside the third reservoir.
7	A pipe, which may comprise a pipeline for transferring water between the first and third storage reservoirs during storing electricity or ‘charging’ and during generating electricity or ‘discharging’. The water in the pipe may comprise a similar density or the same density as the ocean water outside the pipe, which may enable a minimal pressure difference between the inside and outside of the pipe and may reduce pipe material cost. It is important to note the pipe may be located on the sea floor, which is not shown in the present figure. ‘7’ may comprise one or more or a combination of pipes. ‘7’ may comprise onshore and / or offshore pipeline. ‘7’ may be located on the seafloor.

10	A subtank, which may be located on the inside of the second reservoir or the second reservoir comprising a rigid tank. '10' may be directly connected to the low density liquid pipeline, '3', and / or may be directly connected to the internal and / or external wall of the second reservoir or the second reservoir comprising a rigid tank. '10' may comprise a sub-tank for storing low density liquid within the second reservoir. '10' may be configured such that if there were a breach in '10', low density liquid would be contained within the internal walls of the second reservoir. Said subtank may comprise liner or membrane. Said subtank may comprise a bladder tank, or a piston tank, or an expandable or collapsible tank or a combination thereof.
Land	Land, which may comprise both land above and below the ocean. Land may comprise a solid.
Ocean	Ocean may comprise liquid water located in the ocean.
Electricity	Electricity may present the flow of electricity to or from the system. If the electricity arrow is pointing toward '4', the system may be storing electricity, by, for example, pumping low density liquid from the first reservoir to the second reservoir. Electricity may be supplied from one or more or a combination of sources, which may include, but are not limited to, an electricity grid, a power generation source, or other sources of electricity. If the electricity arrow is pointing away from '4', the system may be generating or discharging electricity, by, for example, allowing low density liquid from the second reservoir to pass through a generator, generating electricity, and into the first reservoir. Electricity may be supplied to one or more or a combination of applications requiring electricity, which may include, but are not limited to, an electricity grid, a commercial demand, a residential demand, an industrial demand, a transportation demand, or other application for electricity.

Additional Description

High Vapor Pressure Low Density Liquids and / or Subsea First Reservoir

[0344] There may be key advantages to placing the first reservoir underwater. For example, by placing the first reservoir underwater, a low density liquid possessing a high vapor pressure may be employed as the low density liquid working fluid. The system may be designed such that the underwater first reservoir is located at a water depth where the hydrostatic pressure of the water is close to the vapor pressure of the low density liquid at the temperature of the ocean water. By placing the tank at a water depth where the vapor pressure inside the underwater first reservoir is similar to the pressure of the water surrounding the first reservoir, the tank installed may require less pressure difference resistance and may possess relatively thinner walls or may be lower cost than a tank storing the same liquid on the surface. Also, advantageously, the temperature of water beneath the ocean may be relatively consistent depending on the climate and location, which may enable simpler prediction of low density liquid vapor pressure and / or design of tank pressure requirement and / or design water depth. Also, advantageously, the temperature of water beneath

the ocean may be relatively consistently below a certain temperature range, which may enable simpler prediction of low density liquid vapor pressure and / or design of tank pressure requirement and / or design water depth.

[0345] As an example, liquid Ethane has a vapor pressure of 2807 kPa at 280°K and 4357 kPa at 300°K, which is equivalent to the hydrostatic pressure of water at about a 286 meter water depth and 445 meter water depth, respectively. The first reservoir and / or pump and / or generator may be placed at, for example, a water depth deeper than 150 meters deep and less deep than 500 meters deep. Ethane remains at a liquid phase, rather than a supercritical phase, below its critical point of 305.322°K. Advantageously, the temperature of ocean water at greater than 150 meter water depth, even in equatorial regions, is generally consistently less than 300°K, which may ensure ethane remains at a liquid phase rather than a supercritical phase. At its liquid phase, Ethane has a density of 304 kg / m³ at 300°K and 383 kg / m³ at 280°K. The present embodiment may be configured similar to the configuration of Figure 74. Alternatively, or additionally, the present embodiment may be configured similar to Figure 55, except where '1', '6', and / or '4' are located underwater, although still at a higher elevation than '2'. Alternatively, or additionally, the present embodiment may be configured similar to other figures herein, although the first reservoir, or third reservoir, or pump/generator, or a combination thereof may be placed under the ocean in figures wherein the first reservoir, or third reservoir, or pump/generator, or a combination thereof may be shown above the ocean or on land adjacent to the ocean. Advantageously, liquid ethane may be more abundant and / or less expensive than other low density liquid options. Advantageously, liquid ethane may possess a lower density liquid than other low density liquid options.

Liquid-Liquid Displacement

[0346] The present embodiment pertains to an energy storage device employing a low density liquid and a high density liquid. Electricity is stored by displacing a high density liquid with a low density liquid and electricity is generated by allowing a high density liquid to displace a low density liquid. In the present embodiment, said displacing occurs in an underwater storage reservoir configured to store both low density liquid and high density liquid. An example high density liquid may include, but is not limited to, water. An example low density liquid may include, but is not limited to, propane, butane, ethane, or LPG. In some embodiments, the underwater storage reservoir may comprise a rigid storage tank. In some embodiments, low density liquid comprises the hydraulic fluid employed in the pump and generator for generating electricity.

[0347] In the underwater storage reservoir in some embodiments, the low-density liquid floats above the high-density liquid. The low density liquid may comprise the hydraulic fluid or working fluid employed in a pump or generator. There are multiple benefits resulting from allowing the low density liquid to float above or be located above the high density liquid inside the underwater storage reservoir. Said benefits may include, but are not limited to, the following:

- By allowing low density liquid to float above high-density liquid the present invention may employ a rigid underwater tank. A rigid underwater tank or rigid underwater structure may be employed to contain or store at least a portion of the low-density liquid. A rigid underwater tank may possess numerous advantages, which may include, but is not limited to, longer lifespan, lower risk of leaks or breaks, and resiliency to the elements.
- In the event of a catastrophic failure or a leak or a break in the underwater storage region which, one or more or a combination of the following beneficial outcomes may occur:
 - The energy storage system may continue to remain operational
 - Low density liquid may be safely removed and / or recoverable by allowing the electricity storage system to generate electricity or ‘discharge’ by allowing low density liquid to be transferred from the underwater reservoir to the reservoir near the surface.
 - Low density liquid may remain within the underwater storage region
 - Low density liquid may not leak or escape the underwater storage region
- Low density liquid may be contained within a rigid region of the underwater storage tank, which may possess longer lasting or safer storage characteristics.
- Low density liquid and water may directly displace each other, while being physically separated
- The present embodiment can employ density-based methods for passive risk mitigation, error correction, and emergency response, which may include, but are not limited to, the following:
 - For example, the present embodiment may employ a floating plug which possesses a density greater than low density liquid and less than water. Said plug may stop liquid flow into the low-density liquid pipe when the water level in the second reservoir is above a pre-defined level. Said plug may prevent water from entering the low-density liquid pipe. Said plug may be employed to ensure a pre-defined minimum volume of low-density liquid is present in the underwater storage reservoir.

- If a barrier or separator breaks, within or
- During charging, low density liquid may displace water downwards and out of the underwater tank through a bottom port in the underwater tank.

[0348] In some embodiments, low density liquid may be prevented from coming into direct contact with the high density liquid by means of a physical separation.

- Said physical separation may comprise a liquid with a density greater than the low density liquid and less than the high density liquid, while being insoluble in both the low density liquid and high density liquid.
- Said physical separation may comprise a solid.
- Said physical separation may comprise a barrier which possesses a density greater than low density liquid and less than high density liquid.
- Said physical separation may comprise an impermeable material, such as a synthetic fabric or liner.
- Said physical separation may be employed to prevent the formation of hydrates.
- Said physical separation may be located below the low density liquid and above the water within the underwater storage reservoir or within a rigid underwater storage tank.
- Said physical separation may be located within the underwater storage reservoir.
- Said physical separation may be present within a tank which comprises rigid construction, which may comprise the underwater storage reservoir.

Containment Cover or Barrier or Boundary (“CB” or “CCB”)

[0349] The present invention may involve a containment cover or boundary or barrier (CB or CBB) over the underwater storage reservoir. CB may capture low density liquid in the event of a leak or accidental release of low density liquid. CB may be located over or above the underwater storage reservoir. CB may comprise a liner or fabric or solid or a sheet or a combination thereof. CB may be configured to funnel low density liquid (if captured) into particular regions of the CB to, for example, facilitate recovery of the LDL. In the event of an accidental release or leak of LDL, LDL or LDL hydrate or LDL composition may rise above the underwater reservoir and may be captured by or float into the CB. CB may be floating above the underwater reservoir and may be anchored to the ocean bottom. CB may be less dense than the ocean water, which may facilitate floatation. Alternatively, or additionally, the CB itself may be suspended or floating due to float(s) attached to the CB. In some embodiments, CB may cover or be above a surface area greater than or equal to the surface area of the underwater reservoir and / or underwater valves or connections. In some embodiments, CB may only cover or be above certain sections of the underwater reservoir,

such as, for example, only covering the surface area above a connection or port. There may be more than one CB. For example, there may be a CB above certain connection points or ports. In some embodiments there may be redundant CBs. For example, a CB may cover a particular port, while another CB may cover the port and / or an entire section of the underwater reservoir.

[0350] CB may comprise materials which are compatible with water and / or the LDL. CB may comprise materials that repel both water and LDL. CB may comprise hydrophobic materials which absorb LDL.

[0351] CB may contain sensors or systems or mechanisms to determine if there is a LDL leak or if LDL has been captured by the CB. For example, said sensors may involve measuring the buoyancy force acting on a CB. If LDL is released and floats into a CB, the buoyancy force acting on the CB will increase, which may be measured by one or more sensors. For example, a sensor or indicator may involve a hydrophobic material which absorbs LDL. If LDL contacts said hydrophobic material, LDL may be absorbed, which may trigger the sensor and / or provide an indicator of the occurrence of a leak or accidental release of LDL. For example, a sensor may involve spectroscopy, which may provide indication of the presence of a new liquid other than ocean water, such as LDL. For example, a sensor may involve a float, which is less density than water and more density than LDL. If LDL leaks in sufficient quantities and collects in the CB, the float may begin to sink within a LDL layer which may form. Other mechanisms for sensors may include, but is not limited to, conductivity, spectroscopy, spectrometric, visible color, absorbance, viscosity, pH, dissolution, polarity, dielectric constant, or a combination thereof.

[0352] A system may be employed to notify system operators of the occurrence of a LDL release. Passive and / or active systems may be employed to remediate the problem or shut down the system or undergo pre-defined procedures or undergo new procedures or a combination thereof autonomously or semi-autonomously or with the presence of a human system operator, or a combination thereof.

Rigid Tank with Interconnected Water Reservoir

[0353] An example embodiment or configuration may comprise a rigid tank with a bladder tank inside to store LDL. The remaining storage volume not occupied by the LDL bladder tank may be occupied by water. The water may be interconnected to or comprise the surrounding or adjacent ocean. The water may comprise water from an interconnected to a water reservoir. Said water reservoir may comprise a surface water reservoir or an underwater reservoir. An underwater water reservoir may comprise a tank containing water interconnected to the rigid tank via a pipe.

The water reservoir may possess similar pressures or equilibrium pressure with the hydrostatic pressure of the ocean.

[0354] Below are some characteristics and attributes of an example embodiment:

- The LDL port in the rigid tank and/or the LDL bladder within the rigid tank may be located in the top portion of the rigid tank and/or away from the water port.
- The water port may be located at the bottom or in the bottom portion of the rigid tank and/or away from the LDL and/or the LDL port.
- The water reservoir may contain freshwater or Deionized water if desired. Freshwater or deionized water may be advantageous to prevent corrosion inside the underwater rigid tank.
- In the event of a break or burst in one or all of the expandable/bladder containment devices, the LDL will remain in the rigid tank. LDL may be safely removed through the LDL port, which may involve the same procedure as is typically employed for discharging/generating electricity in the present invention
- Because LDL port is near the top of the rigid tank and/or LDL is stored near top of tank, LDL may rise to the top of the rigid tank, which may prevent LDL from leaking and/or escaping to the surrounding water body or ensure LDL is contained within the system or ensure the LDL is salvageable for the system.
- If LDL were to mix with water inside the underwater rigid tank, LDL hydrates may form, which may be significantly more dense than the LDL. If the underwater tank is full of LDL, the underwater reservoir may be designed to ensure the rigid tank water port clogs with LDL hydrates to prevent escape of LDL from the water port. Said design may include, but is not limited to, a filter or screen in the port which may intentionally clog or collect solids in the event LDL hydrates form.
- If LDL hydrates form, LDL hydrates may sink to the bottom of the tank or float in the interface between water and the LDL
- In the event of a leak or rupture or a detection of hydrate formation, one or more valves may close. For example, the water pipe or port may possess a valve which closes. Similarly, the LDL port or pipe may possess a valve which closes.
- The present embodiment possesses multiple redundancies. The present embodiment may enable LDL to remain contained within a rigid structure or rigid tank, which may ensure the LDL does not escape into the surrounding ocean and / or may ensure LDL is recoverable or salvageable and / or the process is operational, even in the event one or more bladders or barriers fail or burst or break. Additionally, the present embodiment may

enable the inside of the rigid tank to be in contact with a water with less corrosive species than ocean water.

Floating Bladder Tank:

[0355] The present invention may pertain to a gravitational energy storage system involving the displacement of water with a low-density liquid, wherein an underwater storage tank is floating above the ocean floor. The floating underwater storage tank may be buoyant due to the floating underwater storage possessing a lower density or lower average density than the surrounding ocean water.

Example Exemplary Embodiments:

Reservoir with Low Density Liquid – Water with Physical Barrier or Separation Between Low Density Liquid and Water

Exemplary Embodiment:

1. A system for storing or generating electricity comprising:
 - [0356] a first storage reservoir configured to be located at a higher elevation and configured to store a fluid which has a lower density than water;
 - [0357] a second storage reservoir configured to be located at a lower elevation and configured to store a fluid which has a lower density than water and water;
 - [0358] a third storage reservoir configured to store water;
 - [0359] a pump; and
 - [0360] a generator;
 - [0361] wherein the pump, generator, and the first, second, and third reservoirs are operatively connected such that electricity is stored by displacing water inside the second storage reservoir into the third reservoir by pumping low density fluid in the first storage reservoir to the second storage reservoir; and
 - [0362] electricity is generated or discharged by allowing water in the third reservoir to displace low density fluid in the second storage reservoir to the first storage reservoir.

Exemplary Embodiment:

1. A system for storing or generating electricity comprising:
 - [0363] a first storage reservoir configured to be near the surface of a body of water and configured to store a fluid which has a lower density than water;
 - [0364] a second storage reservoir configured to be located below the surface of the body of water;
 - [0365] a pump; and

[0366] a generator;

[0367] wherein the pump, generator, and the first and second reservoir are operatively connected such that electricity is stored by displacing water inside the second storage reservoir by pumping low density fluid in the first storage reservoir to the second storage reservoir and electricity is generated or discharged by allowing the low density fluid in the second storage reservoir to return to the first storage reservoir;

[0368] wherein the second storage reservoir is configured to store water and a low-density liquid.

Exemplary Embodiment:

1. A system for storing or generating electricity comprising:

[0369] a first storage reservoir configured to be near the surface of a body of water and configured to store a fluid which has a lower density than water;

[0370] a second storage reservoir configured to be located below the surface of the body of water;

[0371] a pump; and

[0372] a generator;

[0373] wherein the pump, generator, and the first and second reservoir are operatively connected such that electricity is stored by displacing water inside the second storage reservoir by pumping low density fluid in the first storage reservoir to the second storage reservoir and electricity is generated or discharged by allowing the low density fluid in the second storage reservoir to return to the first storage reservoir;

[0374] wherein the second storage reservoir is a rigid tank configured to store water and a low-density liquid.

Example Exemplary Embodiment

1. A system for storing or generating electricity comprising:

[0375] a first storage reservoir configured to be near the surface of a body of water and configured to store a low density liquid;

[0376] a second storage reservoir configured to be located below the surface of the body of water;

[0377] a pump; and

[0378] a generator;

[0379] wherein the pump, generator, and the first and second reservoir are operatively connected such that electricity is stored by displacing water inside the second storage reservoir by

pumping the low density liquid in the first storage reservoir to the second storage reservoir and electricity is generated or discharged by allowing the low density liquid in the second storage reservoir to return to the first storage reservoir;

[0380] wherein the second storage reservoir is configured to store the water and the low density liquid and wherein the low density liquid has a density below the density of liquid water.

Example Exemplary Subembodiments

2. The system of exemplary embodiment 1 wherein said second storage reservoir comprises a rigid tank.
3. The system of exemplary embodiment 1 wherein the low density liquid is located above water inside the second reservoir.
4. The system of exemplary embodiment 1 wherein the low density liquid floats above water inside the second reservoir.
5. The system of exemplary embodiment 1 wherein the system further comprises a hydraulic fluid in the pump and wherein the hydraulic fluid is the same as the low density liquid.
6. The system of exemplary embodiment 1 wherein the pump, generator, and the first and second reservoir are operatively connected by a pipe.
7. The system of exemplary embodiment 6 wherein the low density liquid is transferred between said first reservoir and said second reservoir using said pipe.
8. The system of exemplary embodiment 1 further comprising a physical barrier within the second reservoir for separating the low density liquid and water in the second reservoir.
9. The system of exemplary embodiment 8 wherein the second reservoir is configured to prevent leakage of the low density liquid in the event of damage to said physical barrier.
10. The system of exemplary embodiment 8 wherein said physical barrier comprises a material with an average density less than liquid water and more than the low density liquid at a temperature greater than 30C and less than 50oC at the same hydrostatic pressure.
11. The system of exemplary embodiment 8 wherein at least a portion of said physical barrier is located above water and at least a portion of said physical barrier is located below the low density liquid.
12. The system of exemplary embodiment 8 wherein said physical barrier comprises a liquid.
13. The system of exemplary embodiment 8 wherein said physical barrier comprises a solid.
14. The system of exemplary embodiment 8 wherein said physical barrier is configured to prevent (1) substantial dissolution of the low density liquid in water, (2) substantial dissolution of water in

the low density liquid, (3) the formation of substantial low density liquid – water hydrates, or a combination thereof.

15. The system of exemplary embodiment 1 which further comprises a barrier situated above at least a portion of the second reservoir.

16. The system of exemplary embodiment 15 wherein said barrier is configured to contain low density liquid, a low density liquid – water composition, or a combination thereof in the event of a breach in the second reservoir.

17. The system of exemplary embodiment 15 wherein said barrier comprises an instrument for detecting low density liquid.

18. The system of exemplary embodiment 15 wherein said barrier is configured to funnel low density liquid to facilitate recovery.

19. The system of exemplary embodiment 15 wherein said barrier is suspended above at least a portion of the second reservoir.

20. The system of exemplary embodiment 19 wherein the barrier is suspended by a tether connected to a mooring, an anchor, the ocean floor, or a combination thereof.

21. The system of exemplary embodiment 15 wherein said barrier is buoyant, connected to buoyant floats, or a combination thereof.

22. The system of exemplary embodiment 1 wherein the second reservoir is buoyant, connected to buoyant floats, or a combination thereof.

23. The system of exemplary embodiment 22 wherein said second reservoir is floating or suspended above the ocean floor.

24. The system of exemplary embodiment 23 wherein the second reservoir is suspended by a tether connected to a mooring, an anchor, the ocean floor, or a combination thereof.

25. The system of exemplary embodiment 1 further comprising a third reservoir operably connected to transfer water displaced by low density liquid during the storing of electricity from the second reservoir to the third reservoir.

26. The system of exemplary embodiment 25 wherein the water has a density which is within +/- 5% the density of ocean water at a temperature greater than 3oC and less than 40oC at the same hydrostatic pressure.

27. The system of exemplary embodiment 25 wherein at least a portion of said third reservoir comprises ocean water.

28. The system of exemplary embodiment 25 wherein at least a portion of said third reservoir comprises treated ocean water.

29. The system of exemplary embodiment 26 wherein at least a portion of said third reservoir possesses a pressure within ± 10 atm of the hydrostatic pressure of the ocean water at the depth of the second reservoir.

Exemplary Subembodiments:

2. The system of embodiment 1 wherein the fluid which has a lower density than water is located above water inside the second reservoir
3. The system of embodiment 1 wherein a fluid which has a lower density than water floats above water inside the second reservoir
4. The system of embodiment 1 wherein the hydraulic fluid or working fluid in the pump and generator comprises the fluid which has a lower density than water
5. The system of embodiment 4 wherein the pump, generator, and the first and second reservoir are operatively connected by a pipe
6. The system of embodiment 5 wherein the fluid which has a lower density than water is transferred between said first reservoir and said second reservoir using said pipe
7. The system of embodiment 1 wherein the fluid which has a lower density than water and water in the second reservoir are separated by a physical barrier
8. The system of embodiment 7 wherein said physical barrier is floating
9. The system of embodiment 7 wherein said physical barrier possesses an average density less dense than water and more dense than the fluid which has a lower density than water
10. The system of embodiment 7 wherein at least a portion of said physical barrier is located above water and below the fluid which has a lower density than water
11. The system of embodiment 7 wherein said physical barrier comprises a liquid
12. The system of embodiment 7 wherein said physical barrier comprises a solid
13. The system of embodiment 7 wherein said physical barrier prevents the dissolution of the fluid which has a lower density than water in water, the dissolution of water in the fluid which has a lower density than water, the formation of fluid which has a lower density than water – water hydrates, or a combination thereof
14. The system of embodiment 1 wherein a containment cover or barrier is situated above one or more parts of the second reservoir
15. The system of embodiment 14 wherein said containment cover or barrier captures or recovers fluid which has a lower density than water or derivatives thereof in the event of a leak or break or accidental release

16. The system of embodiment 14 wherein said containment cover or barrier contains systems for detecting the capture of fluid which has a lower density than water
17. The system of embodiment 14 wherein said containment cover or barrier is configured to funnel fluid which has a lower density than water or derivatives thereof to facilitate capture or recovery
18. The system of embodiment 14 wherein said containment cover or barrier is suspended above at least a portion of the second reservoir, third reservoir, or both
19. The system of embodiment 18 wherein said suspending is conducted by a tether which is connected to a mooring or an anchor or the ocean floor or a combination thereof
20. The system of embodiment 14 wherein said containment cover or barrier is buoyant or connected to buoyant floats or a combination thereof
21. The system of embodiment 1 wherein the second reservoir is buoyant or connected to buoyant floats or a combination thereof
22. The system of embodiment 21 wherein said second reservoir is floating above the ocean floor
23. The system of embodiment 22 wherein said second reservoir is suspended above the ocean floor
24. The system of embodiment 23 wherein said suspending is conducted by a tether which is connected to a mooring or an anchor or the ocean floor or a combination thereof
25. The system of embodiment 1 wherein the third reservoir comprises a liquid with the same density as ocean water
26. The system of embodiment 1 wherein the third reservoir comprises a liquid with a density which is within +/- 0.5%, or 1%, or 2%, or 3%, or 4%, or 5%, or 6%, or 7%, or 8%, or 9%, or 10% of the density of ocean water
26. The system of embodiment 1 wherein the third reservoir comprises a liquid with a density which is within +/- 0.5%, or 1%, or 2%, or 3%, or 4%, or 5%, or 6%, or 7%, or 8%, or 9%, or 10% of the density of ocean water, which may be a liquid at a temperature greater than 30°C and less than 40°C at the same hydrostatic pressure
27. The system of embodiment 1 wherein the third reservoir comprises at least a portion ocean water
28. The system of embodiment 26 wherein said liquid is less corrosive than ocean water, or is less prone to the formation of biofouling or scaling than ocean water, or a combination thereof
29. The system of embodiment 26 wherein said liquid comprises treated ocean water

30. The system of embodiment 26 wherein at least a portion of said liquid is at a pressure with 10 atm of the hydrostatic pressure of ocean water near the second reservoir

1. A system for storing or generating electricity comprising:

[0381] a first storage reservoir configured to be located at a higher elevation and configured to store a fluid which has a lower density than water;

[0382] a second storage reservoir configured to be located at a lower elevation;

[0383] a third storage reservoir configured to store water;

[0384] a pump; and

[0385] a generator;

[0386] wherein the pump, generator, and the first, second, and third reservoirs are operatively connected such that electricity is stored by displacing water inside the second storage reservoir into the third reservoir by pumping low density fluid in the first storage reservoir to the second storage reservoir; and

[0387] electricity is generated or discharged by allowing water in the third reservoir to displace low density fluid in the second storage reservoir to the first storage reservoir;

[0388] wherein the second storage reservoir is configured to store water and a low-density liquid.

1. A system for storing or generating electricity comprising:

[0389] a first storage reservoir configured to be located at a higher elevation and configured to store a fluid which has a lower density than water;

[0390] a second storage reservoir configured to be located at a lower elevation and configured to store low density liquid and water;

[0391] a third storage reservoir configured to store water;

[0392] a pump; and

[0393] a generator;

[0394] wherein the pump, generator, and the first, second, and third reservoirs are operatively connected such that electricity is stored by displacing water inside the second storage reservoir into the third reservoir by pumping low density fluid in the first storage reservoir to the second storage reservoir; and

[0395] electricity is generated or discharged by allowing water in the third reservoir to displace low density fluid in the second storage reservoir to the first storage reservoir.

1. A system for storing or generating electricity comprising:

[0396] a first storage reservoir configured to be near the surface of a body of water and configured to store a fluid which has a lower density than water;

[0397] a second storage reservoir configured to be located below the surface of the body of water;

[0398] a pump; and

[0399] a generator;

[0400] wherein the pump, generator, and the first and second reservoir are operatively connected such that electricity is stored by displacing water inside the second storage reservoir by pumping low density fluid in the first storage reservoir to the second storage reservoir and electricity is generated or discharged by allowing the low density fluid in the second storage reservoir to return to the first storage reservoir;

[0401] wherein the second storage reservoir is configured to store water and a low-density liquid.

1. A system for storing or generating electricity comprising:

[0402] a first storage reservoir configured to be near the surface of a body of water and configured to store a fluid which has a lower density than water;

[0403] a second storage reservoir configured to be located below the surface of the body of water;

[0404] a pump; and

[0405] a generator;

[0406] wherein the pump, generator, and the first and second reservoir are operatively connected such that electricity is stored by displacing water inside the second storage reservoir by pumping low density fluid in the first storage reservoir to the second storage reservoir and electricity is generated or discharged by allowing the low density fluid in the second storage reservoir to return to the first storage reservoir;

[0407] wherein the second storage reservoir is configured to store water and a low-density liquid;

[0408] wherein low density liquid comprises the hydraulic fluid in the pump and generator;

[0409] wherein low density liquid is located above water inside the second storage reservoir

2. The system of embodiment 1 wherein the low-density liquid is located above water inside the second reservoir

3. The system of embodiment 1 wherein the low-density liquid floats above water inside the second reservoir

4. The system of embodiment 1 wherein the hydraulic fluid or working fluid in the pump and generator comprises low density liquid
5. The system of embodiment 4 wherein the pump, generator, and the first and second reservoir are operatively connected by a pipe
6. The system of embodiment 5 wherein said low density liquid is transferred between said first reservoir and said second reservoir using said pipe
7. The system of embodiment 1 wherein the water and low-density liquid in the second reservoir are separated by a physical barrier
8. The system of embodiment 7 wherein said physical barrier is floating
9. The system of embodiment 7 wherein said physical barrier possesses an average density less dense than water and more dense than low density liquid
10. The system of embodiment 7 wherein said physical barrier is located above water and below low density liquid
11. The system of embodiment 7 wherein said physical barrier comprises a liquid
12. The system of embodiment 7 wherein said physical barrier comprises a solid
13. The system of embodiment 1 wherein said physical barrier prevents the dissolution of low density liquid in water, the dissolution of water in low density liquid, the formation of low density liquid – water hydrates, or a combination thereof
1. A system for storing or generating electricity comprising:
 - [0410] a first storage reservoir configured to be near the surface of a body of water and configured to store a fluid which has a lower density than water;
 - [0411] a second storage reservoir configured to be located below the surface of the body of water;
 - [0412] a pump; and
 - [0413] a generator;
 - [0414] wherein the pump, generator, and the first and second reservoir are operatively connected such that electricity is stored by displacing water inside the second storage reservoir by pumping low density fluid in the first storage reservoir to the second storage reservoir and electricity is generated or discharged by allowing the low density fluid in the second storage reservoir to return to the first storage reservoir;
 - [0415] wherein the second storage reservoir is configured to store water and low-density liquid;
 - [0416] wherein the water and low density liquid are separated by a physical barrier

1. A system for storing or generating electricity comprising:

[0417] a first storage reservoir configured to be near the surface of a body of water and configured to store a fluid which has a lower density than water;

[0418] a second storage reservoir configured to be located below the surface of the body of water;

[0419] a pump; and

[0420] a generator;

[0421] wherein the pump, generator, and the first and second reservoir are operatively connected such that electricity is stored by displacing water inside the second storage reservoir by pumping low density fluid in the first storage reservoir to the second storage reservoir and electricity is generated or discharged by allowing the low density fluid in the second storage reservoir to return to the first storage reservoir;

[0422] wherein the second storage reservoir is configured to store water and low-density liquid;

[0423] wherein the water and low density liquid are separated by a floating physical barrier

1. A system for storing or generating electricity comprising:

[0424] a first storage reservoir configured to be near the surface of a body of water and configured to store a fluid which has a lower density than water;

[0425] a second storage reservoir configured to be located below the surface of the body of water;

[0426] a pump; and

[0427] a generator;

[0428] wherein the pump, generator, and the first and second reservoir are operatively connected such that electricity is stored by displacing water inside the second storage reservoir by pumping low density fluid in the first storage reservoir to the second storage reservoir and electricity is generated or discharged by allowing the low density fluid in the second storage reservoir to return to the first storage reservoir;

[0429] wherein the water and low-density liquid in the second storage reservoir are in direct contact in a water – low density liquid liquid-liquid interface

1. A system for storing or generating electricity comprising:

[0430] a first storage reservoir configured to be near the surface of a body of water and configured to store a fluid which has a lower density than water;

[0431] a second storage reservoir configured to be located below the surface of the body of water;

[0432] a pump; and

[0433] a generator;

[0434] wherein the pump, generator, and the first and second reservoir are operatively connected such that electricity is stored by displacing water inside the second storage reservoir by pumping low density fluid in the first storage reservoir to the second storage reservoir and electricity is generated or discharged by allowing the low density fluid in the second storage reservoir to return to the first storage reservoir;

[0435] wherein the second storage reservoir contains a low density liquid – water liquid-liquid interface

Containment Cover or Containment Barrier (“CB” or “CCB”):

Floating / Buoyant Tank:

1. A system for storing or generating electricity comprising:

[0436] a first storage reservoir configured to be near the surface of a body of water and configured to store a fluid which has a lower density than water;

[0437] a second storage reservoir configured to be located below the surface of the body of water and configured to store a fluid which has a lower density than water;

[0438] a pump; and

[0439] a generator;

[0440] wherein the pump, generator, and the first and second reservoir are operatively connected such that electricity is stored by displacing water adjacent the second storage reservoir by pumping low density liquid in the first storage reservoir to the second storage reservoir and electricity is generated by allowing the low density fluid in the second storage reservoir to return to the first

[0441] storage reservoir; and,

[0442] wherein the water and the fluid which has a lower density than water are both in liquid form; and,

[0443] wherein the second storage reservoir is floating.

2. The system of embodiment 1 wherein said floating is anchored to the bottom of the ocean

3. The system of embodiment 1 wherein said floating is suspended above the bottom of the ocean

Condensable Gas in Surface Water Tank:**Rigid Tank with Example Interconnected Pressure Equalizing**

1. An energy storage system comprising:

[0444] A surface tank, A Subsea tank, A pipe, A pump, and A generator;

[0445] Wherein Energy is stored by displacing water in said subsea tank using a low density liquid

[0446] Wherein Energy is generated by allowing water to displace low density liquid in said Subsea tank

1. An energy storage system comprising:

[0447] A surface tank, A Subsea tank, A pipe, A pump, and A generator;

[0448] Wherein Energy is stored by pumping low density liquid into the Subsea tank to displace water in said subsea tank

2. Wherein the pressure inside said Subsea tank is at equilibrium with the hydrostatic pressure of the surrounding water

3. Wherein the Subsea tank contains a water - low density liquid interface

4. Wherein water inside the Subsea tank is in direct contact with the low density liquid

5. Wherein water inside the Subsea tank is separated from the low density liquid by a floating barrier

1. A rigid tank with a low density liquid and water configured to store LDL and water; and,

[0449] A bladder tank configured to store water;

2. Wherein the bladder tank is located at the same elevation as the rigid tank;

3. Wherein the bladder tank is located at an elevation different from the rigid tank

[0450] Note: The location of the bladder tank and elevation of the bladder tank relative to the rigid tank may be virtually any elevation beneath the water body because the water inside the tank is at the same density as the water in the surrounding water body.

Notes

- **Note:** Bladder tank is sunk as a fully collapsed tank and may be connected to the rigid tank, via, for example, a pipe. The rigid tank is sunk by flooding the rigid tank. As the water in the rigid tank is being displaced by the LDL, the displaced water filled the bladder tank. The bladder tank may be floating or sit on the ocean bottom.
- **Note:** The energy storage system may be charged when at a partially charged state.
- **Note:** The energy storage system may be charged when at a fully discharged state.

- **Note:** The energy storage system may be discharged when at a partially charged or partially discharged state.
- **Note:** The energy storage system may be discharged when at a fully charged state.
- **Note:** It may be desirable for the pressure of the water transferred to or from the surface water tank ('inside water') to equal to the gravitational hydrostatic pressure of the water surrounding the pipes ('outside water'). Alternatively, or additionally, the pressure of the inside water may be less than or greater than the outside water by the pressure tolerance of a subsea tank, or one or more components or parts in contact with inside water, or a combination thereof. An example method to ensure the pressure of inside water and outside water is similar is to place a valve or pressure regulator between surface water tank(s) and subsea tank(s). For example, said valve or pressure regulator may be attached to or inside a pipeline connecting surface water tank(s) and subsea tank(s).
- **Note:** It may be desirable for the pressure inside the second reservoir to be the same as the hydrostatic pressure surrounding or adjacent to the second reservoir. The pressure inside the second reservoir may differ from the pressure of the hydrostatic pressure surrounding or adjacent to the second reservoir by less than 10 PSI, or 15 PSI, or 20 PSI, or 1 atm, or 2 atm, or 3 atm, or 4 atm, or 5 atm, or 6 atm, or 7 atm, or 8 atm, or 9 atm, or 10 atm, or 11 atm, or 12 atm, or 15 atm, or 20 atm, or 30 atm, or 40 atm, or 50 atm, or 60 atm, or 70 atm, or 80 atm, or 90 atm, or 100 atm.
- **Note:** Inside the underwater storage reservoir, the low density liquid or the high density liquid may be enclosed in a bladder tank within a rigid underwater tank. For example, the water may be enclosed within a bladder tank inside the rigid underwater tank, while the low density liquid may float above said bladder tank. For example, the low density liquid may be enclosed within a bladder tank inside the rigid underwater tank, while the water may sink below or may be present below said bladder tank. Water inside the rigid underwater tank may comprise or be fluid connected or may be in hydrostatic pressure equilibrium with adjacent or surrounding ocean water.
- **Note:** In some embodiments, the separator or physical barrier may comprise a layer of a solid hydrate of low density liquid,. Said solid hydrate may possess a density greater than low density liquid and less than water. Said solid hydrate layer may inhibit further mixing or formation of hydrate.
- **Note:** The pump / generator in the present invention may comprise a Hydraulic Power Recovery Turbine (HPRT). HPRTs may be currently employed as pump / generator in,

including, but not limited to, the hydrocarbon transport, processing, and refining industries. HPRTs are known to be more energy efficient with lower viscosity of the working fluid. The present invention may employ ultra-low viscosity liquids, such as liquid propane, liquid butane, or LPG, which may possess a substantially lower viscosity than water, which may enable the HPRT to possess a round trip efficiency greater than the round-trip efficiencies associated with water.

- **Note:** The surface water tank or the third reservoir configured to store water on the surface or at a higher elevation than the second reservoir may comprise a rigid tank or a bladder tank or a combination thereof. For example, the third reservoir configured to store water and / or located near, on, or above the ocean surface may comprise a bladder tank, which may be at a pressure in equilibrium with the pressure outside or adjacent to said third reservoir.
- **Note:** Fluid properties affect HPRT efficiency in the same manner as in centrifugal pumps, with higher-viscosity fluids reducing the efficiency. The fact that propane and some other example LDLs have a lower viscosity than water means some LDLs may have a greater energy efficiency / round trip efficiency in an HPRT than water
- **Note:** HPRTs can operate most efficiently at certain ranges of capacity utilization (flow rate) and pressure head. HPRTs are generally most efficient closer to their maximum capacity utilization and pressure head. There are multiple methods to ensure near maximum efficiency in the pump / generator, when, for example, employing HPRTs, which may include, but are not limited to, one or more or a combination of the following:
 - Multiple smaller HPRTs may be employed, wherein HPRTs which are running are run at or near maximum efficiency and / or maximum capacity (highest efficiency is near or at highest capacity). If the demand for storing power changes, the number and / or capacity of the HPRTs online or 'on' for storing power may be adjusted. If the demand for generating power changes, the number and / or capacity of the HPRTs online or 'on' for generating power may be adjusted.
 - If the energy requiring storing is less than the capacity of the HPRTs there may be a few options:
 - Design the system with an additional lower capacity HPRTs (e.g. 2 or 3 or 4 or 5 or more HPRTs which are each a fraction of the total capacity of each of the larger HPRTs). Each of said lower capacity HPRTs may

operate at near maximum efficiency and / or maximum capacity when in operation

- For charging variations which are a fraction of the capacity of the few lower capacity HPRTs or the lowest capacity HPRT, fly-wheels or capacitors or Li-Ion batteries or other standard energy storage devices may be employed to fill in this relatively smaller storage need. Said ‘other standard energy storage devices’ may be discharged to charge the liquid displacement energy storage technology by powering a pump (such as a HPRT) when desirable or may supply electricity directly to the grid or application or a combination thereof.

- **Note:** The floating subsea tank may be rigid or collapsible / expandable or a combination thereof. The floating subsea tank may be suspended over the seafloor by tethers or anchors or attachment lines or other mechanisms.
- **Note:** In the event of a subsea landslide or other catastrophic event, the floating subsea tank may be designed to disconnect from its tether(s) and / or pipeline(s) as part of an emergency disconnect system. Said emergency disconnect system may enable the subsea tank to float to the surface, which may enable to subsea tank to avoid rupture or other catastrophic failure, which may otherwise occur due to debris from an underwater landslide or other catastrophic event.
- **Note:** A floating subsea tank may enable the tank to be easier to implement when, for example, the seafloor is uneven or steep or otherwise challenging for the placement of a tank on the seafloor surface.
- **Note:** Installation of a floating subsea bladder tank may involve, for example:
 - 1) Sinking a fully collapsed bladder tank to the ocean floor
 - 2) Attaching bladder tank tethers and / or anchors to the ocean floor and / or to moorings or weights. Attaching LDL pipeline to the bladder tank.
 - 3) Using the LDL pipeline, add LDL to the bladder tank, resulting in the bladder tank becoming buoyant. The bladder tank may be floating above the ocean floor and / or suspended above the ocean floor due to, including, but not limited to, one or more or a combination of the following: tethers or anchors.
- **Note:** LDL pipeline may be placed or sunk to the ocean bottom while containing or full of LDL. LDL pipeline may be weighted or attached to anchors or weights or a combination thereof to, for example, prevent the LDL pipeline from floating to the ocean surface.

- **Note:** LDL pipeline may be placed or sunk to the ocean bottom. LDL pipeline may be flooded with ocean water during the sinking process. Once on the ocean bottom or once placed in the appropriate location, water in the LDL pipeline may be displaced with LDL by pumping LDL into the pipeline and / or allowing displaced ocean water to exit the pipeline. Displaced ocean water may exit the pipeline, for example, into the surrounding ocean or into a separate containment tank. Said separate containment tank, if employed may be temporary or permanent. When the pipeline is sufficiently full of LDL, one or valves may be closed to, for example, prevent the escape of LDL to the surround ocean and / or prevent the intrusion of ocean water into the LDL pipeline. Alternatively, or additionally, said pipeline may be attached to an underwater tank or a floating underwater tank, when, for example, the pipeline is sufficiently full of LDL. LDL pipeline may be weighted or attached to anchors or weights or a combination thereof to, for example, prevent the LDL pipeline from floating to the ocean surface.
- **Note:** The minimum volume or amount of LDL in the floating underwater tank may comprise the minimum amount of LDL required to ensure the floating underwater tank is buoyant.
- **Note:** One or more or a combination of components of the present invention may be located underground or partially underground. For example, the first storage reservoir, which may comprise a rigid tank on land or underwater, may be located underground. For example, one or more or a portion of or a combination of pipes or valves or pumps or generators may be located underground or partially underground. For example, the second reservoir, which may comprise an underwater rigid tank, may be located underground.
- **Note:** Placing one or more tanks or other components underground may conceal the tanks from public view, which may increase safety and / or reduce the potential eyesore of a tank. Placing one or more tanks or other components underground may increase the longevity of said tanks. Placing one or more tanks or other components underground may increase the system's resilience to severe weather, natural disasters, or man-made risks.
- **Note:** '8' may be buoyant, or neutrally buoyant, or may be at a greater density than the surrounding water body, or a combination thereof. For example, the density of a subsea tank may vary depending on the volume or amount of liquid stored in the tank.
- **Note:** LPG, propane, butane, or other liquified gases, which may be employed as low density liquids, may be semi-refrigerated or partial refrigerated or refrigerated in the surface storage tanks. By employing semi-refrigerated storage, the surface storage tanks

or floating storage tanks or the first reservoir may be capable of greater carrying capacity or may be lower capital cost or a combination thereof.

- **Note:** The low density liquid may be stored at ambient temperatures and / or temperatures matching or near the temperature of the water surrounding the second storage reservoir and / or may be stored pressurized.
- **Note:** It may be desirable to employ butane or butane-propane mixtures or a combination thereof due to butane's higher boiling point and lower vapor pressure than propane and the potential to build larger, lower cost pressure vessels.
- **Note:** Refrigerated or semi-refrigerated or partially refrigerated or cooled vessels may comprise temperatures less than or equal to one or more or a combination of the following: 50°C, or 40°C, or 30°C, or 20°C, or 10°C, or 5°C, or, 0°C, or -10°C, or -20°C, or -30°C, or -40°C, or -50°C.
- **Note:** A configuration involving a subsea rigid tank configured to store water and LDL and a separate or interconnected bladder tank configured to stored water may be advantageous, due to, for example, including but not limited to, one or more or a combination of the following:
 - No need for a water pipeline to the surface or for a tank on the surface
 - Bladder tank underwater is storing primarily water, instead of LDL.
 - A bladder tank may possess a longer longevity or lifespan with water compared to LDL
 - A bladder tank configured for water may be less expensive or comprise less expensive materials than a bladder tank configured for LDL
 - In the event of a rupture or catastrophic failure of the bladder tank, a valve in the pipe connecting the bladder tank to the rigid tank may be closed, which may comprise an emergency shutdown procedure. If said valve fails to close, LDL in the rigid tank will naturally remain in the rigid tank, For example, LDL may remain in the rigid tank due to the location or configuration of the pipe connecting the rigid tank to the bladder tank. Advantageously, in the event of a catastrophic failure or rupture of the bladder tank, the pressure inside the rigid tank will likely remain constant and the composition of the water inside the rigid tank may remain constant.

- Bladder tank enables the rigid underwater tank to experience the same pressure inside the tank as the pressure outside the tank or the pressure of the surrounding hydrostatic pressure.
- **Note:** Some embodiments may involve a floating separator separating water from the LDL in an underwater tank
- **Note:** The round trip electrical efficiency may be greater than or equal to 30%, or 40%, or 50%, or 60%, or 70%, or 80%, or 90%
- **Note:** The present invention may contain multiple pipelines, surface tanks, subsea tanks, HPRT units or pump generator units, valves, other components or a combination thereof.
- **Note:** Rigid tank or rigid containment structure, which may surround at least a portion or the top of an internal sub-reservoir or sub-tank, which may comprise a flexible structure or expandable or collapsible structure, such as a bladder. Said rigid structure may comprise a steel tank or composite tank or a combination thereof. In the event the internal sub-tank breaks or leaks, the leaked low density liquid may remain inside the rigid tank or rigid containment structure, preventing exposure of the low density liquid to the surrounding environment. Alternatively, or additionally, the internal sub-tank may store water, while low density liquid may be stored in the rigid tank. Alternatively, or additionally, the low density liquid and the water are stored in internal sub-tank inside the rigid tank or rigid containment structure. The 'rigid containment structure' may also or alternatively be a flexible structure
- **Note:** Dashed line in figure may indicate a labelling line. The dashed line or dashed box may indicate a label only. Dashed lines or dashed boxes may not be process elements in and of themselves.
- **Note:** Boxes with dashed lines in the figures and dash lines in figures are labels only and are no in and of themselves components of the figure.
- **Note:** The figures may not be to scale. The water depth of, for example, the second reservoir, may be deeper than or equal to, one or more or a combination of the following: 200 meters, or 300 meters, or 400 meters, or 500 meters, or 600 meters, or 700 meters, or 800 meters, 900 meters, or 1,000 meters, 1,100 meters, or 1,200 meters, or 1,300 meters, or 1,400 meters, or 1,500 meters, or 1,600 meters, or 1,700 meters, 1,800 meters, or 1,900 meters, or 2,000 meters, 2,100 meters, or 2,200 meters, or 2,300 meters, or 2,400 meters, or 2,500 meters, or 2,600 meters, or 2,700 meters, 2,800 meters, or 2,900, or 3,000 meters

- **Note:**
 - The water reservoir may comprise a liquid of the same density as the surrounding or adjacent ocean water and in pressure equilibrium with the surrounding or adjacent ocean water.
 - It may be desirable to prevent mixing between the water in the water reservoir and the surrounding ocean water. To prevent said mixing, it may be desirable to employ a flexible barrier between the water reservoir and the surrounding ocean water, which may be classified as a water reservoir boundary layer.
 - If the water reservoir were to break or experience catastrophic failure or is at risk of breaking or catastrophic failure, a valve in a pipe interconnecting the water reservoir with the rigid tank may close, if desired. Said valve may prevent low density liquid or other contents of the rigid tank or end-to-end system from leaking or contaminating the surrounding ocean. If said valve were to fail to close, the rigid tank and pipes may be configured such that low-density liquid naturally remains in the tank and / or minimally escapes or leaks from the rigid tank. For example, said low density liquid may be present floating above water in the second reservoir and said pipe interconnecting the water reservoir with the rigid tank may be located beneath the low density liquid – water liquid-liquid interface.
- **Note:** Reservoirs may comprise multiple interconnected reservoirs or tanks or storage vessels or multiple interconnected process elements or a combination thereof. For example, the an underwater storage reservoir may comprise multiple interconnected underwater tanks.
- **Note:** The third reservoir may enable the same hydrostatic pressure as ocean water, while possessing properties which are less corrosive or less prone to biofouling than ocean water. For example, the third reservoir may comprise ocean water treated with an oxygen scavenger to remove dissolved oxygen and / or prevent corrosion. For example, the third reservoir may comprise ocean water treated with a biocide or a non-corrosive or non-oxidizing biocide. For example, the third reservoir may comprise an aqueous solution with the same or similar density as ocean water, except comprising a different mixture or compositions of salts and / or other reagents than ocean water which may be less corrosive or possess other advantageous properties compared to ocean water. For example, the third reservoir may comprise an aqueous solution with the same or similar density as ocean

water, except comprising reagents which inhibit the formation of low density liquid – water hydrates. For example, the third reservoir may comprise deep sea ocean water, which may comprise low dissolved oxygen concentrations and may be less corrosive compared to surface ocean water.

- **Note:** Separator or Flexible tank or bladder inside rigid tank may be removable or replaceable. This enables the separator or Flexible tank or bladder inside rigid tank to undergo maintenance or be replaced at or near its end of life.
- **Note:** Low density liquid may include, but is not limited to, one or more or a combination of the following: propane, butane, ethane, pentane, hexane, LPG, gas-liquids, oils, or other low density liquids described herein, or other liquids described in the art.
- **Note:** Ocean water temperature is generally between -2°C and 40°C. Deep ocean water is generally about 4°C.
- **Note:** The density of the Low Density Liquid is less than water at least in the temperature range of greater than 3°C and / or less than 40°C.
- **Note:** If the third reservoir is located underwater, a condensable gas in the headspace may ensure the pressure inside the third reservoir is close to the hydrostatic pressure of the ocean at the same underwater depth, which may be beneficial if, for example, said the third reservoir is a rigid tank. The vapor pressure of the condensable headspace gas may be tuned or engineered to ensure it matches or is close to hydrostatic pressure of the ocean at the same underwater depth at the expected operating temperature. The expected operating temperature may range from, for example, -2°C to 50°C, depending on the water body, the depth, the time of year, the surface temperature, the local climate, the water temperature surrounding or in contact with one or more components of the system, other conditions, or a combination thereof.
- **Note:** The pipe connection between an underwater tank and a pipe may be designed to be capable of safe disconnection or re-connection or both. An underwater tank may be disconnected from a pipe for maintenance or replacement or expansion or monitoring of the underwater tank, underwater pipe, other underwater component, or a combination thereof. In some instances, an underwater tank or pipe or both may contain low density liquid during disconnection. An underwater tank may be disconnected from a pipe for maintenance or replacement. In some instances, an underwater tank or pipe or both may contain low density liquid during disconnection. In some instances, low density liquid may be removed from an underwater tank before disconnecting said underwater tank. Safe

disconnection may involve minimal or no leaks of low density liquid. Some embodiments of the present invention may be designed to enable replacement or maintenance of an underwater tank. Some embodiments of the present invention may be designed to enable the transfer of an underwater tank to the surface and / or return of said underwater tank to its original location. Some embodiments of the present invention may enable one or more components or subcomponents of an underwater tank or other underwater components to be removed, or replaced, or maintained if desirable. Some embodiments of the present invention may enable the addition of one or more tanks underwater while integrating with pre-existing underwater infrastructure and / or surface infrastructure. For example, a Separator or Flexible tank or bladder inside a rigid tank may be removable or replaceable.

- Removability or replaceability may involve the ability to remove or replace a component while maintaining operations or with minimal disruption to operations.

Additional Notes:

Example Cost Drivers

- The larger the scale, the lower the cost per kWh energy storage capacity and cost per kW of power capacity
- The deeper the ocean water depth, the greater the energy density and the smaller the required tank volume and pipe diameter per a kWh and kW of storage capacity, respectively. To ensure the project can be constructed with pipelaying techniques and subsea services, projects may initially employ depths less than or equal to a 3,000 meter ocean water depth. As pipelaying techniques and subsea services advance, depths greater than a 3,000 meter ocean water depth may be employed.
- The more hours of energy storage (i.e. the more energy storage capacity relative to power capacity), the lower the cost per kWh
 - Pipe diameter is driven by the energy density and required ‘power capacity’
 - Tank volume is driven by the energy density and required ‘energy storage capacity’
- The distance to electricity grid and electricity grid transmission equipment and / or upgrades to electricity grid infrastructure
- The proximity to onshore and offshore EPC assets and logistics for the delivery and installation of equipment and materials

Example Revenue Drivers (Maximizing Revenue and ROI)

- Price per kWh of electricity in local electricity market and expected power purchase agreement prices / terms
- Demand for grid services due to intermittency of renewables on electricity grid
- Potential of solar or wind in location
- Structure of electricity market and relationship with the electricity grid and / or local electric power utility
- Economic Model: Solar + Storage Project (PPA) vs. Grid Services

Additional Notes:

[0451] Propane gas or LPG gas or refrigerant or near room temperature boiling point liquid or liquid condensable at room temperature or a combination thereof in the headspace of the rigid water tank on the surface.

[0452] Example purpose of condensable gas in water tank

- 1) to enable the tank to remain rigid without forming a vacuum when water exits
- 2) to enable the water to not release any propane into the air. A dilute concentration of propane may exist in the water due to the high pressures under the water enabling some propane solubility. Because the present embodiment is closed / not open to air, the propane cannot be released into the air.

[0453] Note: The headspace may be occupied by a hydrocarbon refrigerant which boils at around room temperature. For example, a combination of butane and pentane. As the water fills the tank, refrigerant compresses and condensed into a liquid (significantly reducing the amount of compression required). The condensed refrigerant forms a floating layer on the water. When the water exits, the refrigerant boils on the surface of the water.

[0454] Note: When water fills up the tank, propane or butane gas may be removed from the tank headspace to enable the water to occupy the space without compressing the propane. The propane gas may be removed via compression into a separate tank.

[0455] Note: Gas inside a water tank or in the headspace of a water tank compressed as water enters the tank. If desirable, said gas may, at least in part, condense.

[0456] Flywheel you compensate for lulls in startup

[0457] It may be desirable for the near room temperature boiling point liquid to be non-flammable. Said near room temperature boiling point liquid may comprise a refrigerant or a combination of refrigerants. For example, said near room temperature boiling point liquid may comprise a fluorinated hydrocarbon

[0458] **Overview:** The present invention may store electricity by displacing water with a low-density liquid (LDL). Electricity may be stored in the form of gravitational potential energy from the gravitational hydrostatic pressure difference between the LDL and water.

Summary Step-by-Step Description:

1. **Storing Electricity:** The valve at the surface is opened (5). LDL in the rigid LDL surface tank (1) is pumped (4) through the pipe (3) into the underwater rigid tank (2). As LDL fills the underwater rigid tank, water inside the tank is displaced. Displaced water travels through the water pipe (7) to the surface water tank (6). When charging is complete, the valve at the surface (5) is closed.
2. **Generating Electricity:** The surface valve (5) is opened. Water inside the surface water tank (6) travels through the water pipe (7) and naturally displaces LDL inside the underwater rigid tank (2). Displaced LDL travels through the LDL pipe (3) and into the generator (4) at the surface, generating electricity, and flowing LDL into the rigid LDL surface tank. When charging is complete, the surface valve (5) is closed.

Example Definitions

- **Supplemental Thermal Storage:** Supplemental thermal storage may comprise a process or system for storing or recovering or both thermal energy from low density liquid, high density liquid, or a combination thereof. Thermal energy recovered may comprise, for example, thermal energy retained in the 'cold' temperature of refrigerated or cooled low density liquid. Supplemental thermal storage may be required to enable an efficient operation in a system with various system components operating at different temperatures. Supplemental thermal storage may be required to enable an efficient operation in a system with a cooled or refrigerated higher elevation low density liquid reservoir which may operate at temperatures lower than surface ocean water or ground or air or combination thereof temperatures.
- **Parasitic Energy:** Energy consumption which reduces system performance or efficiency or both.
- **Non-Parasitic Energy:** Energy consumption which has a negligible impact or no impact or positive impact or a combination thereof on system performance or efficiency or both.
- **Reservoir or Tank:** Reservoir or tank may comprise an equipment or a device for storing material, such as low density liquid or higher density liquid or both. Reservoir or tank may be used interchangeably. It is important to note that in some instances, reservoir may be used broadly to describe the general storage of a fluid or fluids in a region, or zone, or

depth, or a range, or a combination thereof. It is important to note that in some instances, tank may be used broadly to describe the general storage of a fluid or fluids in a region, or zone, or depth, or a range, or a combination thereof. It is important to note that in some instances, tank may be used narrowly to describe an individual storage unit for the storage of a fluid or fluids in a region, or zone, or depth, or a range, or a combination thereof. It is important to note that in some instances, reservoir may be used narrowly to describe an individual storage unit for the storage of a fluid or fluids in a region, or zone, or depth, or a range, or a combination thereof.

- **Higher Elevation Reservoir:** Liquid storage located at an elevation higher than the elevation of a lower elevation reservoir in the same storage system.
- **Lower Elevation Reservoir:** Liquid storage located at an elevation lower than the elevation of a higher elevation reservoir in the same storage system.
- **Low Density Liquid or Lower Density Liquid or LDL:** A working fluid which has a lower density than a high density liquid. A working fluid which has a lower density than a different working fluid with which it exchanges pressure.
- **High Density Liquid or Higher Density Liquid or HDL or Greater Density Liquid:** A working fluid which has a higher density than a low density liquid. A working fluid which has a greater g/mL density than a low density liquid. A working fluid which has a higher density than a different working fluid with which it exchanges pressure.
- **Cooling or ‘Refrigerate’:** Removing heat from liquid or system or both. Removing heat using, for example, heat transfer, heat exchange, refrigeration cycle, radiant cooling, or other heat removal, or a combination thereof.
- **Partially Refrigerated:** A reservoir or working fluid or both which is cooled to a temperature less than at least some ambient temperature. A reservoir or working fluid or both which is cooled to a temperature less than at least some ambient temperature, although the working fluid may require a pressure greater than atmospheric pressure to be stored at a liquid phase.
- **Working Fluid:** A liquid or gas or both which is employed in the system to store potential energy or heat or both.
- **Thermal Storage Medium or Thermal Storage Media or Thermal Storage Liquid:** A material which stores, or transfers, or a combination thereof heat.
- **‘Cold’ Thermal Storage Medium or ‘Cold’ Thermal Storage Media:** Material which is at a temperature colder than ‘Warm’ Thermal Storage Medium or ‘Warm’ Thermal

Storage Media. ‘Cold’ Thermal Storage Medium or ‘Cold’ Thermal Storage Media may be at or near the temperature of refrigerated or cooled low density liquid or near or at the temperature of low density liquid in a cooled or refrigerated or semi-refrigerated higher elevation low density liquid reservoir. For example, ‘Cold’ Thermal Storage Medium or ‘Cold’ Thermal Storage Media may be at a temperature of refrigerated or cooled low density liquid plus or minus the heat exchanger losses and other potential losses.

- **‘Warm’ Thermal Storage Medium or ‘Warm’ Thermal Storage Media:** Material which is at a temperature warmer than ‘Cold’ Thermal Storage Medium or ‘Cold’ Thermal Storage Media. ‘Warm’ Thermal Storage Medium or ‘Warm’ Thermal Storage Media may be at a temperature above the temperature of refrigerated or cooled low density liquid or above the temperature of low density liquid in a cooled or refrigerated or semi-refrigerated higher elevation low density liquid reservoir.
- **‘Cold’:** A temperature of a medium which is a temperature less than the same medium at a ‘warm’ temperature. In some embodiments, ‘cold’ may be a temperature less than an ambient air temperature or an ambient water temperature or an ambient ground temperature or a combination thereof. In some embodiments, ‘cold’ may be a temperature near or at or less than the temperature or temperature range of a cooled or refrigerated or semi-refrigerated low density liquid reservoir.
- **‘Warm’:** A temperature of a medium which is a temperature greater than the same medium at a ‘warm’ temperature. In some embodiments, ‘warm’ may be a temperature greater than an ambient air temperature or an ambient water temperature or an ambient ground temperature or a combination thereof. In some embodiments, ‘warm’ may be a temperature near or at or greater than the temperature or temperature range of a cooled or refrigerated or semi-refrigerated low density liquid reservoir.
- **‘Cold’ Low Density Liquid:** Low density liquid at a temperature less than ‘warm’ low density liquid. In some embodiments, ‘cold’ low density liquid may be a temperature of a low density liquid where the low density liquid possesses a vapor pressure near or equal to or less than the pressure limit or pressure rating of a cooled or refrigerated or semi-refrigerated higher elevation low density liquid reservoir
- **‘Warm’ Low Density Liquid:** Low density liquid at a temperature greater than ‘cold’ low density liquid. In some embodiments, ‘warm’ low density liquid may be a temperature of a low density liquid where the low density liquid possesses a vapor pressure near or

equal to or greater than the pressure limit or pressure rating of a cooled or refrigerated or semi-refrigerated higher elevation low density liquid reservoir

- **Thermal Management:** A process for removing, adding, or otherwise transferring heat. A process which may monitor and / or adjust the temperature of one or more or a combination of fluids or components and may, automatically or with oversight or both, make adjustments or add or remove heat or a combination thereof.
- **Low Boiling Point Low Density Liquid or High Vapor Pressure Low Density Liquid:** A liquid with a vapor pressure about equal to or greater than 1 atm at potential ambient temperature conditions. In some embodiments, a low boiling point liquid may comprises a liquid with a vapor pressure about equal to or greater than 1 atm at a temperature less than 60 degrees Celsius, or 50 degrees Celsius, or 40 degrees Celsius, or a combination thereof. In some embodiments, a low boiling point liquid may comprises a liquid with a vapor pressure about equal to or greater than 1 atm at a temperature less than 100 degrees Celsius, or 90 degrees Celsius, or 80 degrees Celsius, or 70 degrees Celsius, or 60 degrees Celsius, or 50 degrees Celsius, or 40 degrees Celsius, or 30 degrees Celsius or a combination thereof.
- **Enhanced Density Higher Density Liquid:** In some embodiments, a liquid with a density greater than water or ocean water or the water of a water body or a combination thereof. In some embodiments, a solution comprising a solvent and reagents with a density greater than said solvent.
- **Insoluble or Limited Solubility:** A reagent or liquid or a combination thereof which possesses a solubility less than 99%, or 90%, or 80%, or 70%, or 60%, or 50%, or 40%, or 30%, or 20%, or 10%, or 5%, or 1% or a combination thereof in another reagent or liquid.
- **Parasitic Load:** The energy or material or a combination thereof demand from processes which reduce the performance or efficiency of a system, although may be required or helpful or desired for said system's operation.
- **Ocean:** May comprise ocean, or a body of water, or a lake, or a body of liquid comprising a high density liquid, or a combination thereof.
- **Higher Density Liquid or High Density Liquid:** A liquid with a density greater than a low density liquid. A liquid with a density greater than a low density liquid within the same energy storage system or process. A liquid with a density less than a high density liquid which it displaces in the energy storage system or process.

- **Lower Density Liquid or High Density Liquid:** A liquid with a density less than a high density liquid. A liquid with a density less than a high density liquid within the same energy storage system or process. A liquid with a density less than a high density liquid which it displaces in the energy storage system or process.

Example Figure Descriptions

[0459] Figure 88: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present embodiment may comprise, including, but not limited to, one or more or a combination of the following: a higher elevation low density liquid reservoir, a cooling system for cooling said higher elevation low density liquid reservoir, a cold supplemental thermal storage reservoir, a warm supplemental thermal storage reservoir, a heat exchanger, a pump and / or generator, a lower elevation reservoir, and interconnecting pipes. The present figure may show the present embodiment storing energy, such as electricity, which may also be referred to as undergoing a state of charging.

[0460] Figure 89: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present embodiment may comprise, including, but not limited to, one or more or a combination of the following: a higher elevation low density liquid reservoir, a cooling system for cooling said higher elevation low density liquid reservoir, a cold supplemental thermal storage reservoir, a warm supplemental thermal storage reservoir, a heat exchanger, a generator and / or pump, a lower elevation reservoir, and interconnecting pipes. The present figure may show the present embodiment generating energy, such as electricity, which may also be referred to as undergoing a state of discharging.

[0461] Figure 90: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present embodiment may comprise, including, but not limited to, one or more or a combination of the following: a higher elevation low density liquid reservoir, a cooling system for cooling said higher elevation low density liquid reservoir, a higher elevation high density liquid reservoir, a cold supplemental thermal storage reservoir, a warm supplemental thermal storage reservoir, a heat exchanger, a generator and / or pump, a lower elevation reservoir, and interconnecting pipes. The present figure may show the present embodiment storing energy, such as electricity, which may also be referred to as undergoing a state of charging.

[0462] Figure 91: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present embodiment may comprise, including, but not limited to, one or more or a combination of the following: a higher elevation low density liquid

reservoir, a cooling system for cooling said higher elevation low density liquid reservoir, a higher elevation high density liquid reservoir, a cold supplemental thermal storage reservoir, a warm supplemental thermal storage reservoir, a heat exchanger, a pump and / or generator, a lower elevation reservoir, and interconnecting pipes. The present figure may show the present embodiment generating energy, such as electricity, which may also be referred to as undergoing a state of discharging.

[0463] Figure 92: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present embodiment may comprise, including, but not limited to, one or more or a combination of the following: a higher elevation low density liquid reservoir, a cooling system for cooling said higher elevation low density liquid reservoir, a supplemental thermal storage reservoir which may possess temperature layers or a temperature gradient, a heat exchanger, a pump and / or generator, a lower elevation reservoir, and interconnecting pipes. The present figure may show the present embodiment storing energy, such as electricity, which may also be referred to as undergoing a state of charging.

[0464] Figure 93: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present embodiment may comprise, including, but not limited to, one or more or a combination of the following: a higher elevation low density liquid reservoir, a cooling system for cooling said higher elevation low density liquid reservoir, a supplemental thermal storage reservoir which may possess temperature layers or a temperature gradient, a heat exchanger, a generator and / or pump, a lower elevation reservoir, and interconnecting pipes. The present figure may show the present embodiment generating energy, such as electricity, which may also be referred to as undergoing a state of discharging.

[0465] Figure 94: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present embodiment may comprise, including, but not limited to, one or more or a combination of the following: a higher elevation low density liquid reservoir, a cooling system for cooling said higher elevation low density liquid reservoir, a higher elevation high density liquid reservoir, a supplemental thermal storage reservoir which may possess temperature layers or a temperature gradient, a heat exchanger, a pump and / or generator, a lower elevation reservoir, and interconnecting pipes. The present figure may show the present embodiment storing energy, such as electricity, which may also be referred to as undergoing a state of charging.

[0466] Figure 95: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present embodiment may comprise, including, but

not limited to, one or more or a combination of the following: a higher elevation low density liquid reservoir, a cooling system for cooling said higher elevation low density liquid reservoir, a higher elevation high density liquid reservoir, a supplemental thermal storage reservoir which may possess temperature layers or a temperature gradient, a heat exchanger, a generator and / or pump, a lower elevation reservoir, and interconnecting pipes. The present figure may show the present embodiment generating energy, such as electricity, which may also be referred to as undergoing a state of discharging.

[0467] Figure 96: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present embodiment may comprise, including, but not limited to, one or more or a combination of the following: a higher elevation low density liquid reservoir, a cooling system for cooling said higher elevation low density liquid reservoir, a heat exchanger, a pump and / or generator, a lower elevation reservoir, and interconnecting pipes. The present figure may show the present embodiment storing energy, such as electricity, which may also be referred to as undergoing a state of charging.

[0468] Figure 97: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present embodiment may comprise, including, but not limited to, one or more or a combination of the following: a higher elevation low density liquid reservoir, a cooling system for cooling said higher elevation low density liquid reservoir, a heat exchanger, a generator and / or pump, a lower elevation reservoir, and interconnecting pipes. The present figure may show the present embodiment generating energy, such as electricity, which may also be referred to as undergoing a state of discharging.

[0469] Figure 98: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present embodiment may comprise, including, but not limited to, one or more or a combination of the following: a higher elevation low density liquid reservoir, a cooling system for cooling said higher elevation low density liquid reservoir, a higher elevation high density liquid reservoir, a supplemental thermal storage reservoir which may possess temperature layers or a temperature gradient, a heat exchanger, a generator and / or pump, a lower elevation reservoir, and interconnecting pipes. The present figure may show the present embodiment generating energy, such as electricity, which may also be referred to as undergoing a state of discharging.

[0470] Figure 99: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present embodiment may comprise, including, but not limited to, one or more or a combination of the following: a higher elevation low density liquid

reservoir, a cooling system for cooling said higher elevation low density liquid reservoir, a heat exchanger, a pump and / or generator, a lower elevation reservoir, and interconnecting pipes. The present figure may show the present embodiment storing energy, such as electricity, which may also be referred to as undergoing a state of charging.

[0471] Figure 100: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present figure may show an embodiment with a higher elevation reservoir low density liquid reservoir and a lower elevation reservoir, wherein the higher elevation reservoir may be located on land and the lower elevation reservoir may be located under water.

[0472] Figure 101: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present figure may show an embodiment with a higher elevation low density liquid reservoir and a lower elevation reservoir, wherein the higher elevation reservoir may be located on land and the lower elevation reservoir may be located underwater.

[0473] Figure 102: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present figure may show an embodiment with a higher elevation low density liquid reservoir and a lower elevation reservoir, wherein the higher elevation reservoir may be located underwater near or on the seabed and the lower elevation reservoir may be located under water near or on the seabed.

[0474] Figure 103: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present figure may show an embodiment with a higher elevation low density liquid reservoir and a lower elevation reservoir, wherein the higher elevation reservoir may be located underwater near or on the seabed and the lower elevation reservoir may be located under water near or on the seabed.

[0475] Figure 104: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present figure may show an embodiment with a higher elevation low density liquid reservoir and a lower elevation reservoir, wherein the higher elevation reservoir may be located in the water as a semi-submersible or fully submersed or combination thereof vessel and the lower elevation reservoir may be located under water near or on the seabed.

[0476] Figure 105: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present figure may show an embodiment with a higher elevation low density liquid reservoir and a lower elevation reservoir, wherein the higher

elevation reservoir may be located in the water as a semi-submersible or fully submersed or combination thereof vessel and the lower elevation reservoir may be located under water near or on the seabed.

[0477] Figure 106: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present figure may show an embodiment with a higher elevation low density liquid reservoir and a lower elevation reservoir, wherein the higher elevation reservoir may be located in the water as a floating vessel and the lower elevation reservoir may be located under water near or on the seabed.

[0478] Figure 107: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present figure may show an embodiment with a higher elevation low density liquid reservoir and a lower elevation reservoir, wherein the higher elevation reservoir may be located in the water as a floating vessel and the lower elevation reservoir may be located underwater near or on the seabed.

[0479] Figure 108: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present figure may show an embodiment with a lower elevation reservoir underwater and / or above and / or on the seabed.

[0480] Figure 109: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present figure may show an embodiment with a lower elevation reservoir underwater and / or above and / or on the seabed.

[0481] Figure 110: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present figure may show an embodiment with a lower elevation reservoir underwater and / or above and / or on the seabed.

[0482] Figure 111: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present figure may show an embodiment with a lower elevation reservoir underwater and / or above and / or on the seabed.

[0483] Figure 112: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present figure may show an embodiment with a lower elevation reservoir underwater and / or underground beneath the seabed or buried or a combination thereof.

[0484] Figure 113: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present figure may show an embodiment with a lower elevation reservoir underwater and / or underground beneath the seabed or buried or a combination thereof.

[0485] Figure 114: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present figure may show an embodiment with a lower elevation reservoir underwater and / or underground beneath the seabed or buried or a combination thereof.

[0486] Figure 115: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present figure may show an embodiment with a lower elevation reservoir underwater and / or underground beneath the seabed or buried or a combination thereof.

[0487] Figure 116: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present figure may show an embodiment with a lower elevation reservoir underground.

[0488] Figure 117: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present figure may show an embodiment with a lower elevation reservoir underground.

[0489] Figure 118: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present figure may show an embodiment with a lower elevation reservoir underground.

[0490] Figure 119: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. The present figure may show an embodiment with a lower elevation reservoir underground.

Example Figure Keys

[0491] Figure 88 and Figure 89:

Label	Description
1	Higher elevation low density liquid reservoir. May comprise one or more storage tanks. May be atmospheric pressure, or semi-pressurized, or pressurized, or a combination thereof. May be semi-refrigerated or fully refrigerated, or non-refrigerated, or a combination thereof.
2	Pipe transferring low density liquid between a heat exchanger and a higher elevation low density liquid reservoir.
3	A heat exchanger. May comprise a heat exchanger or process for heat exchanging or recovering 'cold' or 'heat' or 'thermal energy' from low density liquid. May a heat exchanger or process for heat exchanging low density liquid and thermal storage liquid.
4	Pipe transferring low density liquid between a heat exchanger and a pump and / or generator.
5	A pump and / or generator.

6	Pipe transferring low density liquid between higher elevation parts and lower elevation parts. Pipe transferring low density liquid between a higher elevation low density liquid reservoir and a lower elevation reservoir.
7	A lower elevation reservoir.
8	A 'warm' thermal storage reservoir.
9	A pipe transferring thermal storage medium or heat transfer liquid or a combination thereof between a warm thermal storage reservoir and a heat exchanger.
10	A pipe transferring thermal storage medium or heat transfer liquid or a combination thereof between a cold thermal storage reservoir and a heat exchanger.
11	A 'cold' thermal storage reservoir.
12	A cooling source or a heat sink or a chiller or a refrigeration process or a compressor or a liquefaction process or cooling process or a combination thereof.
13	Represents the transfer of heat transfer fluid or fluids or heat or a combination thereof between '12' and '1'.
Higher Elevation	Label for an adjacent dashed box. Said adjacent dashed box may contain high elevation parts.
Lower Elevation	Label for an adjacent dashed box. Said adjacent dashed box may contain lower elevation parts.

[0492] Figure 90 and Figure 91:

Label	Description
1	Higher elevation low density liquid reservoir. May comprise one or more storage tanks. May be atmospheric pressure, or semi-pressurized, or pressurized, or a combination thereof. May be semi-refrigerated or fully refrigerated, or non-refrigerated, or a combination thereof.
2	Pipe transferring low density liquid between a heat exchanger and a higher elevation low density liquid reservoir.
3	A heat exchanger. May comprise a heat exchanger or process for heat exchanging or recovering 'cold' or 'heat' or 'thermal energy' from low density liquid. May a heat exchanger or process for heat exchanging low density liquid and thermal storage liquid.
4	Pipe transferring low density liquid between a heat exchanger and a pump and / or generator.
5	A pump and / or generator.
6	Pipe transferring low density liquid between higher elevation parts and lower elevation parts. Pipe transferring low density liquid between a higher elevation low density liquid reservoir and a lower elevation reservoir.
7	A lower elevation reservoir.
8	A 'warm' thermal storage reservoir.
9	A pipe transferring thermal storage medium or heat transfer liquid or a combination thereof between a warm thermal storage reservoir and a heat exchanger.
10	A pipe transferring thermal storage medium or heat transfer liquid or a combination thereof between a cold thermal storage reservoir and a heat exchanger.

11	A 'cold' thermal storage reservoir.
12	A cooling source or a heat sink or a chiller or a refrigeration process or a compressor or a liquefaction process or cooling process or a combination thereof.
13	Represents the transfer of heat transfer fluid or fluids or heat or a combination thereof between '12' and '1'.
14	A pipe transferring high density liquid between a lower elevation reservoir and higher elevation reservoir.
15	A higher elevation high density liquid reservoir.
Higher Elevation	Label for an adjacent dashed box. Said adjacent dashed box may contain high elevation parts.
Lower Elevation	Label for an adjacent dashed box. Said adjacent dashed box may contain lower elevation parts.

[0493] Figure 92 and Figure 93:

Label	Description
1	Higher elevation low density liquid reservoir. May comprise one or more storage tanks. May be atmospheric pressure, or semi-pressurized, or pressurized, or a combination thereof. May be semi-refrigerated or fully refrigerated, or non-refrigerated, or a combination thereof.
2	Pipe transferring low density liquid between a heat exchanger and a higher elevation low density liquid reservoir.
3	A heat exchanger. May comprise a heat exchanger or process for heat exchanging or recovering 'cold' or 'heat' or 'thermal energy' from low density liquid. May a heat exchanger or process for heat exchanging low density liquid and thermal storage liquid.
4	Pipe transferring low density liquid between a heat exchanger and a pump and / or generator.
5	A pump and / or generator.
6	Pipe transferring low density liquid between higher elevation parts and lower elevation parts. Pipe transferring low density liquid between a higher elevation low density liquid reservoir and a lower elevation reservoir.
7	A lower elevation reservoir.
8	A thermal storage reservoir. May comprise a thermal storage reservoir with a temperature gradient or thermocline or temperature layers. May comprise a tank. May comprise a tank with a barrier between warm and / or cold regions of said tank. Said barrier may comprise, for example, a sub-bladder tank or a floating barrier or a combination thereof.
9	A pipe transferring thermal storage medium or heat transfer liquid or a combination thereof between a thermal storage reservoir and a heat exchanger.
10	A pipe transferring thermal storage medium or heat transfer liquid or a combination thereof between a thermal storage reservoir and a heat exchanger.
11	A cooling source or a heat sink or a chiller or a refrigeration process or a compressor or a liquefaction process or cooling process or a combination thereof.
12	Represents the transfer of heat transfer fluid or fluids or heat or a combination thereof between '12' and '1'.
Higher Elevation	Label for an adjacent dashed box. Said adjacent dashed box may contain high elevation parts.

Lower Elevation	Label for an adjacent dashed box. Said adjacent dashed box may contain lower elevation parts.
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[0494] Figure 94 and Figure 95:

Label	Description
1	Higher elevation low density liquid reservoir. May comprise one or more storage tanks. May be atmospheric pressure, or semi-pressurized, or pressurized, or a combination thereof. May be semi-refrigerated or fully refrigerated, or non-refrigerated, or a combination thereof.
2	Pipe transferring low density liquid between a heat exchanger and a higher elevation low density liquid reservoir.
3	A heat exchanger. May comprise a heat exchanger or process for heat exchanging or recovering 'cold' or 'heat' or 'thermal energy' from low density liquid. May a heat exchanger or process for heat exchanging low density liquid and thermal storage liquid.
4	Pipe transferring low density liquid between a heat exchanger and a pump and / or generator.
5	A pump and / or generator.
6	Pipe transferring low density liquid between higher elevation parts and lower elevation parts. Pipe transferring low density liquid between a higher elevation low density liquid reservoir and a lower elevation reservoir.
7	A lower elevation reservoir.
8	A thermal storage reservoir. May comprise a thermal storage reservoir with a temperature gradient or thermocline or temperature layers. May comprise a tank. May comprise a tank with a barrier between warm and / or cold regions of said tank. Said barrier may comprise, for example, a sub-bladder tank or a floating barrier or a combination thereof.
9	A pipe transferring thermal storage medium or heat transfer liquid or a combination thereof between a thermal storage reservoir and a heat exchanger.
10	A pipe transferring thermal storage medium or heat transfer liquid or a combination thereof between a thermal storage reservoir and a heat exchanger.
11	A cooling source or a heat sink or a chiller or a refrigeration process or a compressor or a liquefaction process or cooling process or a combination thereof.
12	Represents the transfer of heat transfer fluid or fluids or heat or a combination thereof between '12' and '1'.
14	A pipe transferring high density liquid between a lower elevation reservoir and higher elevation reservoir.
15	A higher elevation high density liquid reservoir.
Higher Elevation	Label for an adjacent dashed box. Said adjacent dashed box may contain high elevation parts.
Lower Elevation	Label for an adjacent dashed box. Said adjacent dashed box may contain lower elevation parts.

[0495] Figure 96 and Figure 97:

Label	Description
1	Higher elevation low density liquid reservoir. May comprise one or more storage tanks. May be atmospheric pressure, or semi-pressurized, or pressurized, or a combination thereof. May be semi-refrigerated or fully refrigerated, or non-refrigerated, or a combination thereof.
2	Pipe transferring low density liquid between a pump and / or generator and a higher elevation low density liquid reservoir.
3	A pump and / or generator.
4	Pipe transferring low density liquid between higher elevation parts and lower elevation parts. Pipe transferring low density liquid between a higher elevation low density liquid reservoir and a lower elevation reservoir.
5	A lower elevation reservoir.
6	A cooling source or a heat sink or a chiller or a refrigeration process or a compressor or a liquefaction process or cooling process or a combination thereof.
7	Represents the transfer of heat transfer fluid or fluids or heat or a combination thereof between '12' and '1'.
Higher Elevation	Label for an adjacent dashed box. Said adjacent dashed box may contain high elevation parts.
Lower Elevation	Label for an adjacent dashed box. Said adjacent dashed box may contain lower elevation parts.

[0496] Figure 98 and Figure 99:

Label	Description
1	Higher elevation low density liquid reservoir. May comprise one or more storage tanks. May be atmospheric pressure, or semi-pressurized, or pressurized, or a combination thereof. May be semi-refrigerated or fully refrigerated, or non-refrigerated, or a combination thereof.
2	Pipe transferring low density liquid between a pump and / or generator and a higher elevation low density liquid reservoir.
3	A pump and / or generator.
4	Pipe transferring low density liquid between higher elevation parts and lower elevation parts. Pipe transferring low density liquid between a higher elevation low density liquid reservoir and a lower elevation reservoir.
5	A lower elevation reservoir.
6	A cooling source or a heat sink or a chiller or a refrigeration process or a compressor or a liquefaction process or cooling process or a combination thereof.
7	Represents the transfer of heat transfer fluid or fluids or heat or a combination thereof between '12' and '1'.
8	A pipe transferring high density liquid between a lower elevation reservoir and higher elevation reservoir.
9	A higher elevation high density liquid reservoir.
Higher Elevation	Label for an adjacent dashed box. Said adjacent dashed box may contain high elevation parts.
Lower Elevation	Label for an adjacent dashed box. Said adjacent dashed box may contain lower elevation parts.

Example Step-by-Step Descriptions of Figures**[0497]** Figure 88:

Charging:

1) 'Cold' low density liquid may be transferred from a refrigerated or cooled higher elevation low density liquid reservoir to a heat exchanger. Said heat exchanger may involve heat exchanging 'cold' low density liquid with 'warm' thermal storage medium, forming 'warm' low density liquid and 'cold' thermal storage medium. 'Cold' thermal storage medium may be stored in a 'cold' thermal storage reservoir. 'Warm' low density liquid is transferred to '2').

2) 'Warm' low density liquid is pumped using one or more pumps to a lower elevation reservoir, where low density liquid displaces high density liquid. Said pump may be powered by energy, such as electricity, and said energy may be stored during said displacing of a high density liquid with a low density liquid.

[0498] Figure 89:

Discharging:

1) Low density liquid in a lower elevation reservoir may be allowed to be displaced by high density liquid. Displaced low density liquid may be transferred in a pipe to a generator, generating electricity. Upon reaching higher elevation parts, which may include said generator, low density liquid may be 'warm', which may mean the low density liquid is at a higher temperature than low density liquid in a cooled or refrigerated higher elevation reservoir.

2) 'Warm' low density liquid may enter a heat exchanger. Said heat exchanger may involve heat exchanging 'warm' low density liquid with 'cold' thermal storage medium, forming 'cold' low density liquid and 'warm' thermal storage medium. 'Warm' thermal storage medium may be stored in a 'warm' thermal storage reservoir. 'Cold' low density liquid may be transferred to a refrigerated or cooled higher elevation low density liquid reservoir.

[0499] Figure 90:

Charging:

1) 'Cold' low density liquid may be transferred from a refrigerated or cooled higher elevation low density liquid reservoir to a heat exchanger. Said heat exchanger may involve heat exchanging 'cold' low density liquid with 'warm' thermal storage medium, forming 'warm' low density liquid and 'cold' thermal storage medium. 'Cold' thermal

storage medium may be stored in a 'cold' thermal storage reservoir. 'Warm' low density liquid is transferred to '2').

2) 'Warm' low density liquid is pumped using one or more pumps to a lower elevation reservoir, where low density liquid displaces high density liquid. Said pump may be powered by energy, such as electricity, and said energy may be stored during said displacing of a high density liquid with a low density liquid. Displaced high density liquid may be transferred through a pipe to a higher elevation high density liquid reservoir.

[0500] Figure 91:

Discharging:

1) Low density liquid in a lower elevation reservoir may be allowed to be displaced by high density liquid in a higher elevation reservoir. High density liquid from a higher elevation reservoir is transferred in a pipe to a lower elevation reservoir, displacing low density liquid in said lower elevation reservoir. Said displaced low density liquid may be transferred in a pipe to a generator, generating electricity. Upon reaching higher elevation parts, which may include said generator, low density liquid may be 'warm', which may mean the low density liquid is at a higher temperature than low density liquid in a cooled or refrigerated higher elevation reservoir.

2) 'Warm' low density liquid may enter a heat exchanger. Said heat exchanger may involve heat exchanging 'warm' low density liquid with 'cold' thermal storage medium, forming 'cold' low density liquid and 'warm' thermal storage medium. 'Warm' thermal storage medium may be stored in a 'warm' thermal storage reservoir. 'Cold' low density liquid may be transferred to a refrigerated or cooled higher elevation low density liquid reservoir.

[0501] Figure 92:

Charging:

1) 'Cold' low density liquid may be transferred from a refrigerated or cooled higher elevation low density liquid reservoir to a heat exchanger. Said heat exchanger may involve heat exchanging 'cold' low density liquid with 'warm' thermal storage medium, forming 'warm' low density liquid and 'cold' thermal storage medium. 'Cold' thermal storage medium may be stored in a thermal storage reservoir. 'Warm' low density liquid may be transferred to '2').

2) 'Warm' low density liquid may be pumped using one or more pumps to a lower elevation reservoir, where low density liquid displaces high density liquid. Said pump may be

powered by energy, such as electricity, and said energy may be stored during said displacing of a high density liquid with a low density liquid.

[0502] Figure 93:

Discharging:

1) Low density liquid in a lower elevation reservoir may be allowed to be displaced by high density liquid. Displaced low density liquid may be transferred in a pipe to a generator, generating electricity. Upon reaching higher elevation parts, which may include said generator, low density liquid may be 'warm', which may mean the low density liquid is at a higher temperature than low density liquid in a cooled or refrigerated higher elevation reservoir.

2) 'Warm' low density liquid may enter a heat exchanger. Said heat exchanger may involve heat exchanging 'warm' low density liquid with 'cold' thermal storage medium, forming 'cold' low density liquid and 'warm' thermal storage medium. 'Warm' thermal storage medium may be stored in a thermal storage reservoir. 'Cold' low density liquid may be transferred to a refrigerated or cooled higher elevation low density liquid reservoir.

[0503] Figure 94:

Charging:

1) 'Cold' low density liquid may be transferred from a refrigerated or cooled higher elevation low density liquid reservoir to a heat exchanger. Said heat exchanger may involve heat exchanging 'cold' low density liquid with 'warm' thermal storage medium, forming 'warm' low density liquid and 'cold' thermal storage medium. 'Cold' thermal storage medium may be stored in a thermal storage reservoir. 'Warm' low density liquid is transferred to '2').

2) 'Warm' low density liquid is pumped using one or more pumps to a lower elevation reservoir, where low density liquid displaces high density liquid. Said pump may be powered by energy, such as electricity, and said energy may be stored during said displacing of a high density liquid with a low density liquid. Displaced high density liquid may be transferred through a pipe to a higher elevation high density liquid reservoir.

[0504] Figure 95:

Discharging:

1) Low density liquid in a lower elevation reservoir may be allowed to be displaced by high density liquid in a higher elevation reservoir. High density liquid from a higher elevation reservoir is transferred in a pipe to a lower elevation reservoir, displacing low

density liquid in said lower elevation reservoir. Said displaced low density liquid may be transferred in a pipe to a generator, generating electricity. Upon reaching higher elevation parts, which may include said generator, low density liquid may be 'warm', which may mean the low density liquid is at a higher temperature than low density liquid in a cooled or refrigerated higher elevation reservoir.

2) 'Warm' low density liquid may enter a heat exchanger. Said heat exchanger may involve heat exchanging 'warm' low density liquid with 'cold' thermal storage medium, forming 'cold' low density liquid and 'warm' thermal storage medium. 'Warm' thermal storage medium may be stored in a thermal storage reservoir. 'Cold' low density liquid may be transferred to a refrigerated or cooled higher elevation low density liquid reservoir.

[0505] Figure 96:

Charging:

[0506] 'Cold' low density liquid is pumped using one or more pumps to a lower elevation reservoir, where low density liquid displaces high density liquid. Said pump may be powered by energy, such as electricity, and said energy may be stored during said displacing of a high density liquid with a low density liquid.

[0507] Figure 97:

Discharging:

[0508] Low density liquid in a lower elevation reservoir may be allowed to be displaced by high density liquid. Said displaced low density liquid may be transferred in a pipe to a generator, generating electricity. Upon reaching higher elevation parts, which may include said generator, low density liquid may be 'warm', which may mean the low density liquid is at a higher temperature than low density liquid in a cooled or refrigerated higher elevation reservoir. Said 'warm' low density liquid may undergo cooling before, during, or after or a combination thereof entering a cooled or refrigerated low density liquid higher elevation reservoir.

[0509] Figure 98:

Charging:

[0510] 'Cold' low density liquid is pumped using one or more pumps to a lower elevation reservoir, where low density liquid displaces high density liquid. Said displaced high density liquid may be transferred in a pipe to a higher elevation high density liquid reservoir. Said pump may be powered by energy, such as electricity, and said energy may be stored during said displacing of a high density liquid with a low density liquid.

[0511] Figure 99:

Discharging:

[0512] Low density liquid in a lower elevation reservoir may be allowed to be displaced by high density liquid in a higher elevation reservoir. High density liquid from a higher elevation reservoir is transferred in a pipe to a lower elevation reservoir, displacing low density liquid in said lower elevation reservoir. Said displaced low density liquid may be transferred in a pipe to a generator, generating electricity. Upon reaching higher elevation parts, which may include said generator, low density liquid may be 'warm', which may mean the low density liquid is at a higher temperature than low density liquid in a cooled or refrigerated higher elevation reservoir. Said 'warm' low density liquid may undergo cooling before, during, or after or a combination thereof entering a cooled or refrigerated low density liquid higher elevation reservoir.

Description

[0513] In some embodiments, the low density liquid may possess a low boiling point. In some embodiments, the external pressure or ambient pressure surrounding a low density liquid reservoir may be less than the vapor pressure of the low density liquid if the low density liquid is stored at ambient temperature. If the pressure of the low density liquid inside a reservoir exceeds the pressure surrounding or adjacent to said reservoir, the reservoir may be 'pressurized' and must be resistant to said pressure to ensure safety and prevent rupture. Pressurized reservoirs, such as ASME pressurized tanks, are utilized for storing butane, propane, LPG, and other volatile liquid storage in the art and may be employed. To enable pressurization and pressure resistance, pressurized tanks may require thicker walls, or stronger reinforcement, or stronger materials, or a combination thereof compared to non-pressurized tanks. As a result, pressurized tanks are generally more expensive than non-pressurized tanks for storing the same mass of volatile liquid. Additionally, among pressurized tanks, the higher the pressure rating or pressure resistance, generally the more expensive the tank.

[0514] In some embodiments, one or more low density liquid reservoirs may be cooled or actively cooled or undergo some form of thermal management. For example, in some embodiments, a higher elevation low density liquid reservoir may be cooled or refrigerated. Cooling or 'refrigerate' may be employed interchangeably, and may simply describe the active removing of heat. For example, in some embodiments, a higher elevation low density liquid storage reservoir may be cooled or refrigerated to reduce the required pressure resistance of a higher elevation low density liquid storage reservoir or enable a higher elevation low density liquid storage reservoir to be non-pressurized or a combination thereof. Refrigerated storage tanks are

utilized for storing butane, propane, LPG, and other volatile liquids in the art and may be employed.

[0515] Active refrigerating or cooling may require energy input and said energy input may be parasitic. The energy required to refrigerate or cool low density liquid may decrease total round trip energy efficiency. Minimizing energy required in refrigerating or cooling a low density liquid storage reservoir may be advantageous to maximizing round trip energy efficiency of the energy storage system.

[0516] In some embodiments, a higher elevation low density liquid storage reservoir may be refrigerated. A refrigerated or cooled storage reservoir may enable lower capital cost due to, for example, the capability of using a non-pressurized tank or less pressurized tank.

[0517] In some embodiments, a refrigerated higher elevation low density liquid storage reservoir may be employed with the integration of supplemental thermal storage. Supplemental thermal storage may be employed to minimize parasitic energy requirements associated with refrigerating or cooling a low density liquid storage reservoir. Supplemental thermal storage may be employed to minimize the required cooling or refrigeration capacity, or ‘cooling tonnage’, to refrigerate or cool a low density liquid storage reservoir, which may minimize the capital cost or energy demands or a combination thereof of the cooling equipment. Supplemental thermal storage may be integrated to recover the ‘cold’ stored in a low density liquid’s specific heat capacity before a low density liquid is transferred to a lower elevation reservoir during the storing of electricity or ‘charging’ of the energy storage system. Supplemental thermal storage may be integrated to cool a low density liquid before transferring said low density liquid into a refrigerated or cooled higher elevation low density liquid storage reservoir during the generation of electricity or ‘discharging’ of the energy storage system.

[0518] There are various systems, methods, and configurations for integrating supplemental thermal storage.

[0519] For example, in some embodiments, an integrated supplemental thermal storage system may involve a thermal storage reservoir, a thermal storage media, a heat transfer media, and a heat exchanger. In the present example, the thermal storage media and the heat transfer media may comprise the same media and may comprise a high heat capacity liquid, which may include, but is not limited to, water, or water with a freezing point depressant, or aqueous salt brine, or aqueous brine, or a liquid-liquid phase transition liquid. In the present example, the thermal storage reservoir may comprise one or more storage tanks which store thermal storage media. In some embodiments, the thermal storage reservoir may comprise one tank with a temperature gradient or

thermocline. In some embodiments, the thermal storage reservoir may comprise two tanks, wherein one tank may be for 'cold' thermal storage media and one tank may be for 'warm' thermal storage media. The present example may a thermal storage reservoir comprising two tanks, one tank for 'cold' thermal storage media and one tank for 'warm' thermal storage media. In the present example, the heat exchanger may comprise a heat exchanger which facilitates heat transfer between the thermal storage media and the low density liquid. The present example may employ normal butane as a low density liquid, although other low density liquids may be employed if desired. The present example may store electricity or energy by pumping a low density liquid from a higher elevation reservoir to a lower elevation reservoir, displacing water in the lower elevation reservoir. The present example may generate electricity or energy by allowing water to displace low density liquid in a lower elevation reservoir, displacing the low density liquid into a pipe to a generator, generating electricity or energy, and into a higher elevation reservoir.

- In the present example, during the storing of electricity, or 'charging', low density liquid exiting or after exiting a refrigerated higher elevation storage reservoir may pass through a heat exchanger, where the 'cold' low density liquid may be heat exchanged with 'warm' thermal storage liquid, which may result in the formation of 'warm' low density liquid and 'cold' thermal storage liquid. The cold thermal storage liquid may be transferred to a thermal storage reservoir. 'Warm' low density liquid may be transferred in a pipe to a lower elevation reservoir. Said heat exchanging may be conducted before, during, or after a pumping step. For example, the present example may involve a first pump which increases the pressure of the 'cold' low density liquid to a pressure greater than the vapor pressure of the low density liquid at the 'warm' temperature range, then, after heat exchanging in the heat exchanger, the resulting 'warm' low density liquid may undergo a subsequent pumping step which increases the pressure of the low density liquid to a pressure sufficient to transfer the low density liquid to a lower elevation reservoir. For example, the present example may involve pumping the 'cold' low density liquid to a pressure sufficient to transfer the low density liquid to the lower elevation reservoir, then heat exchanging said 'cold' low density liquid with 'warm' heat transfer liquid, and transferring the resulting 'warm' low density liquid to a lower elevation reservoir. In some embodiments, the heat exchanging may occur before or during the transferring of the low density liquid to a lower elevation reservoir. In some embodiments, the heat exchanger may comprise, including, but not limited to, one or more or a combination of the following: a shell in tube heat exchanger, or a plate heat exchange, or a coil wrapped around a low

density liquid pipe, a thermally conductive low density liquid pipe segment, or one or more heat exchanging methods known in the art.

- In the present example, during the generation of electricity, or ‘discharging’, low density liquid before, during, or after, or a combination thereof entering a generator may pass through a heat exchanger, where the ‘warm’ low density liquid may be heat exchanged with ‘cold’ thermal storage liquid, which may result in the formation of ‘cold’ low density liquid and ‘warm’ thermal storage liquid. The warm thermal storage liquid may be transferred to a thermal storage reservoir. ‘Cold’ low density liquid may be transferred to a higher elevation reservoir, which comprise a cooled or refrigerated higher elevation reservoir. In some embodiments, said ‘cold’ low density liquid resulting from said heat exchange may be at a temperature near, or equal to, or less than the temperature of a refrigerated or cooled higher elevation low density liquid reservoir. The present example may involve generating electricity from the high pressure warm low density liquid, which may depressurize the ‘warm’ low density liquid to a pressure greater than the vapor pressure of the low density liquid at the ‘warm’ temperature, then, after heat exchanging in the heat exchanger, the resulting ‘cold’ low density liquid may enter a second generator or depressurization step which may decrease the pressure of the ‘cold’ low density liquid to a pressure appropriate from transfer into a cooled or refrigerated low density liquid storage reservoir. The present example may involve generating electricity from the high pressure warm low density liquid, then heat exchanging the warm low density liquid to form cold low density liquid, then transferring the cold low density liquid into a higher elevation low density liquid storage reservoir. In some embodiments, the warm low density liquid entering the heat exchanger may be at a pressure greater than or equal to the vapor pressure of the low density liquid at the ‘warm’ temperature and the ‘cold’ low density liquid exiting the heat exchanger may be at a pressure sufficient for transfer into a cooled or refrigerated higher elevation low density liquid reservoir. In some embodiments, the warm low density liquid entering the heat exchanger may be at a pressure greater than or equal to the vapor pressure of the low density liquid at the ‘warm’ temperature and the ‘cold’ low density liquid exiting the heat exchanger may require further depressurization before transfer into a cooled or refrigerated higher elevation low density liquid reservoir. In some embodiments, the warm low density liquid entering the heat exchanger may be at a pressure greater than or equal to the vapor pressure of the low density liquid at the ‘warm’ temperature and the ‘cold’ low density liquid exiting the heat exchangers may require

further depressurization before transfer into a cooled or refrigerated higher elevation low density liquid reservoir. In some embodiments, the heat exchanger may comprise, including, but not limited to, one or more or a combination of the following: a shell in tube heat exchanger, or a plate heat exchange, or a coil wrapped around a low density liquid pipe, a thermally conductive low density liquid pipe segment, or one or more heat exchanging methods known in the art.

- In some embodiments, the pump and generator may comprise the same unit, such as a reversible pump/generator or hydraulic power recovery turbine.
- In some embodiments, the same heat exchanger may be employed during charging as is employed during discharging.

[0520] In embodiments employing cooled or refrigerated low density liquid storage tanks, supplemental thermal storage may be beneficial to maximizing system round trip efficiency. The calculations for an example system are shown below:

- In the present example system, liquid normal butane may be provided as an example low density liquid.
- In the present example, the example outside ambient temperature is 30 degrees Celsius.
- The present example comprises 1 GWh of energy storage
- With a lower elevation reservoir located at a water depth of about 3,000 meters and a higher elevation reservoir located at an elevation of about 0 meters, the present example requires about 235,294 cubic meters of liquid normal butane or about 134,823 metric tons of liquid normal butane at a density of 573 kg per cubic meter.
- Liquid normal butane has a boiling point of about -1°C at atmospheric pressure
- The liquid butane in the present example may be stored in a refrigerated higher elevation reservoir at about -3°C when at a stable state or emptying, and -1°C when the higher elevation reservoir is filling.
- The present example stores electricity (charging) by pumping a low density liquid from a higher elevation reservoir to a lower elevation reservoir, displacing water in the lower elevation reservoir.
- The present example generates electricity (discharging) by allowing water to displace a low density liquid in lower elevation reservoir, and the displaced low density liquid is transferred in a pipe to a generator, generating electricity, and into a higher elevation reservoir.

- For the purposes of the present example, the temperature of the low density entering at least one higher elevation part of the system (higher elevation parts may include, but are not limited to, higher elevation pipe segments, the generator, tanks, reservoirs, and / or any heat exchangers) during discharging may be at the ambient temperature, which for the present example is 30 degrees Celsius. In practice, the temperature of the low density liquid entering at least one higher elevation part of the system during discharging may be lower than ambient temperature due to the lower temperature of the deep ocean (generally about 0 to 5°C) and the generally colder temperature of the ocean (the temperature of the ocean in most of the world, including at surface water depths, is generally less than 30°C most of the year).
- The present example shows a full charge/discharge cycle, where the higher elevation reservoir is practically emptied during charging and practically filled during discharging. In practice, an energy storage system may operate at various charge and discharge states, an may undergo charging or discharging or a combination thereof when a higher elevation reservoir is partially filled or empty or full or a combination thereof.
- The heat exchanger temperature difference between heat exchanged fluids is assumed to be about 1°K
- The ‘warm’ thermal storage liquid is assumed to be at the example ambient temperature, or 30 degrees Celsius. In practice, the ‘warm’ thermal storage liquid may be at a temperature less than ambient due to, for example, including, but not limited to, the returning low density liquid during discharging being at a temperature less than ambient, or due to thermal management systems, or due to a combination thereof.
- The specific heat capacity of liquid normal butane is 2.275 J/g°K
- The heat capacity of 134,823 metric tons of liquid normal butane is 306,722 MJ/°K
- As shown in the below examples with calculations, an example embodiment with a refrigerated or cooled higher elevation low density liquid reservoir with supplemental thermal storage may require significantly less cooling energy or parasitic cooling than an example embodiment with a refrigerated or cooled higher elevation low density liquid reservoir without supplemental thermal storage. As shown in the below examples with calculations, an example embodiment with a refrigerated or cooled higher elevation low density liquid reservoir without supplemental thermal storage may require a parasitic load or reduction in round trip efficiency of about 14 - 28% for cooling. As shown in the below examples with calculations, an example embodiment with a refrigerated or cooled higher

elevation low density liquid reservoir with supplemental thermal storage may require a parasitic load or reduction in round trip efficiency of about 1 – 3% for cooling. Clearly, a supplemental thermal storage system can be advantageous to maximize the round trip efficiency of embodiments employing a refrigerated higher elevation low density liquid reservoir. Additionally, a supplemental thermal storage system can be advantageous to minimizing CAPEX, due to the smaller cooling capacity requirements in embodiments employing a refrigerated higher elevation low density liquid reservoir with supplemental thermal storage compared to embodiments employing a refrigerated higher elevation low density liquid reservoir without supplemental thermal storage.

- Version of the present example with supplemental thermal storage:
 - Steps
 - 1) Charging: During charging from 0% to 100% charged, 134,823 metric tons of ‘cold’ liquid normal butane at a temperature of -3°C exits a refrigerated or cooled higher elevation reservoir and is heat exchanged with ‘warm’ thermal storage liquid. Exiting the heat exchange is ‘cold’ thermal storage liquid at -2°C and ‘warm’ liquid normal butane at a temperature of 29°C. The ‘warm’ low density liquid may be transferred to a lower elevation reservoir. The thermal storage liquid may be stored in a thermal storage reservoir. In some embodiments, ‘cold’ thermal storage liquid in a thermal storage reservoir may be maintained at or near a design ‘cold’ temperature. Said maintaining may involve, for example, including, but not limited to, refrigeration, other forms of cooling, insulation, radiative cooling, or other forms of thermal management.
 - 2) Discharging: During discharging from 100% to 0%, 134,823 metric tons of ‘warm’ liquid normal butane enters a heat exchange with ‘cold’ thermal storage liquid. For the present example, the ‘warm’ liquid normal butane is 30°C and the ‘cold’ thermal storage liquid is -2°C. Exiting the heat exchange is ‘warm’ thermal storage liquid at 29°C and ‘cold’ liquid normal butane at a temperature of -1°C. The ‘cold’ liquid normal butane is transferred into a refrigerated or cooled higher elevation low density liquid reservoir. The ‘warm’ thermal storage liquid is transferred into a thermal storage reservoir.

- Cooling Energy Consumption
 - In the present example, it may be desirable for the normal liquid butane to be cooled to a design storage temperature or design emptying temperature. In the present example, normal liquid butane in a refrigerated or cooled higher elevation low density liquid storage reservoir may be cooled from a temperature of -1°C to a temperature of -3°C. Said cooling may occurring during filling or during storage or during emptying or a combination thereof.
 - With a heat capacity of 306,722 MJ/°C, cooling from -1°C to -3°C requires the removal of 613,444 MJ of heat.
 - Using a refrigeration cycle or cooling system with a coefficient of performance of 6, cooling will require 102,241 MJ of electricity or 28.4 MWh of electricity. The present example energy storage system stores 1 GWh of electricity, so 28.4 MWh of electricity is a cooling parasitic load of 2.84% or reduces the overall round trip efficiency of the energy storage system by about 2.84%.
 - Using a refrigeration cycle or cooling system with a coefficient of performance of 15, which may assume the use of deep ocean seawater as a heat sink or lower ambient temperatures or lower wet bulb temperatures, or a combination thereof, cooling will require 40,896 MJ of electricity or 11.36 MWh of electricity. The present example energy storage system stores 1 GWh of electricity, so 11.36 MWh of electricity is a cooling parasitic load of 1.136% or reduces the overall round trip efficiency of the energy storage system by about 1.136%.
- Note: In some embodiments, a cold thermal storage may be cooled to a design temperature lower than or equal to the design low density liquid storage temperature before, during, or after or a combination thereof heat exchange with 'cold' low density liquid.
- Version of the present example without supplemental thermal storage:
 - Steps
 - 1) Charging: During charging from 0% to 100% charged, 134,823 metric tons of 'cold' liquid normal butane at a temperature of -3°C exits

a refrigerated or cooled higher elevation reservoir. The ‘cold’ low density liquid is transferred directly to the lower elevation reservoir.

- 2) Discharging: During discharging from 100% to 0%, 134,823 metric tons of ‘warm’ liquid normal butane enters higher elevation parts. For the present example, the ‘warm’ liquid normal butane is ambient temperature, which for this example is 30°C. In practice, ‘warm’ low density liquid may be colder than ambient temperature or may be warmer than ambient temperature or both. In the present example, ‘warm’ liquid butane must be cooled from 30°C to -3°C, or at least to -1°C, before entering a refrigerated or cooled low density liquid higher elevation reservoir.

- Cooling Energy Consumption

- In the present example, ‘warm’ liquid butane must be cooled from 30°C to -3°C, or at least to -1°C. Said cooling may occur during filling or during storage or during emptying or a combination thereof.
- With a heat capacity of 306,722 MJ/°C, cooling from 30°C to -3°C requires the removal of 10,121,826 MJ of heat.
- Using a refrigeration cycle or cooling system with an average coefficient of performance of 10, cooling will require 1,012,183 MJ of electricity or 281.2 MWh of electricity. The present example energy storage system stores 1 GWh of electricity, so 281.2 MWh of electricity is a cooling parasitic load of 28.12% or reduces the overall round trip efficiency of the energy storage system by about 28.12%.
- Using a refrigeration cycle or cooling system with a coefficient of performance of 20, which may assume the use of deep ocean seawater as a heat sink or lower ambient temperatures or lower wet bulb temperatures, or a combination thereof, cooling will require 506,091 MJ of electricity or 140.58 MWh of electricity. The present example energy storage system stores 1 GWh of electricity, so 140.58 MWh of electricity is a cooling parasitic load of 14.058% or reduces the overall round trip efficiency of the energy storage system by about 14.058%.

[0521] In some embodiments, ‘cold’ thermal storage medium may be maintained at a temperature less than or equal to the temperature of low density liquid in a refrigerated or cooled

low density liquid storage reservoir. Said maintaining may involve some form of thermal management. For example, said thermal management may involve systems and methods for cooling or temperature control or temperature monitoring or a combination thereof described herein or known in the art or a combination thereof. In some embodiments, a thermal management system employed for a 'cold' thermal storage medium may be overlapping or integrated with the thermal management system employed in cooling a refrigerated low density liquid storage reservoir. In some embodiments, a thermal management system employed for a 'cold' thermal storage medium may be separate from the thermal management system employed in cooling a refrigerated low density liquid storage reservoir.

[0522] Additional systems and methods for minimizing parasitic energy consumption related to cooling or refrigerating a low density liquid reservoir may include, but are not limited to:

- Insulating the reservoir
- Efficient refrigerators
- Employing the evaporation or boiling of low density liquid inside the low density liquid reservoir cool the low density liquid in said reservoir. The resulting low density liquid vapors may be recirculated internally by, for example, condensing said vapors into a liquid by means of compression, cooling, or both. Said condensed low density liquid vapors, which may comprise liquid low density liquid, may be returned to a low density liquid reservoir at a liquid phase. Alternatively or additionally, said low density liquid vapors may be used for another application, which may include, but is not limited to, as a fuel or an industrial feedstock or a chemical feedstock or a refrigerant, or a combination thereof.
- Employing evaporative cooling
- Employing water based evaporative cooling
- Employing cold deep ocean temperatures to cool or as a heat transfer medium
- Radiant cooling
- OTEC
- Seawater cooling
- Employing seawater as a heat sink for a refrigerator or chiller
- Employing cold deep sea water as a heat sink for a refrigerator or chiller
- Employing reflective or non-light or heat absorbing colors or coatings on tanks
- Employing thermal storage
- Employing high density liquid or water or both, which may be located within the energy storage system as system working fluids, as a 'heat' sink to cool a refrigerated or cooled

low density liquid reservoir or a supplemental thermal storage reservoir or both. In some embodiments, high density liquid or water or both in a lower elevation reservoir are displaced to a higher elevation reservoir during charging. Said displaced high density liquid or water or both may be at a lower temperature than ambient temperature due to, for example, the potentially relatively lower temperature of the deep ocean than some ambient temperatures and / or heat exchanging with the deep ocean. For example, said displaced high density liquid or water or both may be heat exchanged with a refrigerated or cooled low density liquid reservoir or a supplemental thermal storage reservoir or both to cool said reservoirs. For example, said displaced high density liquid or water or both may be employed as a heat sink for a refrigeration cycle employed to cool or remove heat from a refrigerated or cooled low density liquid reservoir or a supplemental thermal storage reservoir or both to cool said reservoirs.

[0523] In some embodiments, a refrigerated higher elevation storage tank may be employed in the absence of supplemental thermal storage. If the cooling or refrigeration methods are non-paritistic in form or require minimal energy or are passive or a combination thereof, the round-trip efficiency of an embodiment with a refrigerated or cooled low density liquid reservoir, such as a refrigerated or cooled low density liquid higher elevation reservoir, may be similar to the round-trip efficiency of embodiments with a non-refrigerated or non-cooled low density liquid reservoir. If the cooling or refrigeration methods are parasitic in form, the round-trip efficiency of an embodiment with a refrigerated or cooled low density liquid reservoir, such as a refrigerated or cooled low density liquid higher elevation reservoir, may be less than the round-trip efficiency of embodiments with a non-refrigerated or non-cooled low density liquid higher elevation reservoir. Some embodiments employing a cooled or refrigerated tank without supplemental thermal storage may possess a lower capital cost than embodiments employing a cooled or refrigerated tank with supplemental thermal storage due to, for example, the capability of using a non-pressurized tank or less pressurized tank and / or the lack of supplemental thermal storage and related heat exchangers. Some embodiments employing a cooled or refrigerated tank without supplemental thermal storage may possess a higher capital cost than embodiments employing a cooled or refrigerated tank with supplemental thermal storage due to, for example, higher cooling capacity requirements in embodiments employing a cooled or refrigerated tank without supplemental thermal storage than in embodiments employing a cooled or refrigerated tank with supplemental thermal storage.

[0524] In some embodiments, energy is stored by pumping a low density liquid to displace a higher density liquid in a lower elevation reservoir and energy is stored by allowing a higher density liquid to displace low density liquid in a lower elevation reservoir. In some of the presently described embodiments, the lower elevation reservoir may be underwater or under-liquid or underground or both. In some embodiments where a lower elevation reservoir is underwater or under-liquid, it may be desirable for the higher density liquid to possess a density similar to or equal to the density of the fluid or liquid surrounding or adjacent to a lower elevation reservoir, which may result in hydrostatic equilibrium and / or minimized pressure differences between the interior and exterior of a lower elevation reservoir. In some embodiments where a lower elevation reservoir is underground, enhanced density higher density liquids may be employed, due to, for example, the ability for ground to exert equilibrium pressure regardless of the density of the higher density liquid.

[0525] In some embodiments where a lower elevation reservoir is underground, the lower density liquid may be in direct contact with the higher density liquid in the lower elevation reservoir. If the lower density liquid is in direct contact with the higher density liquid, it may be desirable for the lower density liquid to be insoluble or possess a limited solubility in the higher density liquid and / or it may be desirable for the lower density liquid to be a non-hydrate forming lower density liquid.

[0526] It is important to note that a lower density liquid may be inherently advantageous to compressed air for reasons in addition to the inherently greater round-trip efficiency of using a lower density liquid to displace a higher density liquid. For example, unlike air, lower density liquid may be in direct contact with water regardless of the pressure or depth or combination thereof, enabling practically unlimited potential energy density and underground depth. Ultra-energy dense embodiments may be envisioned, which may include, but is not limited to, underground or underwater or under-liquid or a combination thereof depths or elevation differences greater than or equal to 1,000 meters, 2,000 meters, or the 3,000 meters, or 4,000 meters, or 5,000 meters, or 6,000 meters, or 7,000 meters, or 8,000 meters, or 9,000 meters, or 10,000 meters, or 11,000 meters, or 12,000 meters, or 13,000 meters, or 14,000 meters, or 15,000 meters, or 20,000 meters, or 25,000 meters, or 30,000 meters, or 35,000 meters, or 40,000 meters, or 45,000 meters, or 50,000 meters. Elevation differences may comprise difference in elevation between a higher elevation reservoir and a lower elevation reservoir, or a first reservoir and a second reservoir, or a first reservoir and a third reservoir, or any combination thereof. On the other hand, air, specifically nitrogen in air, forms gas hydrates at pressures above 173 bar (about 1,730

meters of hydrostatic water head), limiting the energy density and depth of systems based on displacing water with air. Additionally, the solubility of air or other gases increases in water with pressure due to Henry's Law. Unlike air, the solubility of some low density liquids in water may not substantially or practically increase with pressure. Additionally, air forms a supercritical fluid at pressures greater than about 30 bar. Unlike air, a liquid generally remains a liquid regardless of pressure, as long as the pressure is above the boiling point pressure of the liquid at the temperature of the liquid.

[0527] In some embodiments, higher density liquid may comprise density enhancers or may comprise a liquid with a density greater than water or both. Increasing the density of a higher density liquid or decreasing the density of the lower density liquid or both increase the energy density of the energy storage system. Embodiments where the higher density liquid and lower density liquid are in a closed system and the lower elevation reservoir is underground or surrounded by solid or both, it may be particularly advantageous to maximize the density of the higher density liquid. For example, higher density liquid or enhanced higher density liquid may include, but is not limited to, one or more or a combination of the following: an aqueous salt solution, an aqueous brine, a liquid salt, a halogen, a heavy liquid, a liquid metal, a concentrated aqueous solution, a urea ammonium nitrate solution, frac water, concentrated frac water, desalination brine, or a mining brine.

[0528] In some embodiments, a lower elevation reservoir may be located in a region with a different temperature than a higher elevation reservoir. Additionally, pipes transferring liquids between reservoirs may transit through regions where the temperature is different from the temperature of a higher elevation reservoir, a lower elevation reservoir, or both. In some embodiments, temperature differences may be harnessed and / or exploited. For example, temperature differences may be harnessed and / or exploited for cooling, heating, or both. For example, temperature differences may be harnessed and/or exploited to generate electricity, desalinate water, facilitate separations, freeze, boil water, or conduct other valuable work or activities.

[0529] Temperature differences may be harnessed and / or exploited during process operations or as an auxiliary benefit of process operations.

- For example, a lower elevation reservoir may be located underwater in a region where the temperature is substantially different from the temperature of the region of the higher elevation reservoir. For example, the temperature of water surrounding or adjacent a lower elevation reservoir underwater may be less than 10 degrees Celsius or less than 5 degrees

Celsius and the temperature of environmental surrounding or adjacent a higher elevation reservoir may be greater than 5 degrees Celsius or greater than 10 degrees Celsius. In embodiments where a higher elevation low density liquid reservoir is partially refrigerated or refrigerated or cooled, it may be desirable to harness or exploit the potentially sub-ambient temperature of low density liquid displaced from a lower elevation reservoir to reduce cooling or refrigerating energy consumption. In embodiments where a higher elevation low density liquid reservoir is partially refrigerated or refrigerated or cooled, it may be desirable to harness or exploit the potentially sub-ambient temperature of low density liquid or high density liquid or both displaced from a lower elevation reservoir to reduce cooling or refrigerating energy consumption. In some embodiments, it may be desirable to harness or exploit the potentially sub-ambient temperature of low density liquid or high density liquid or both displaced from a lower elevation reservoir to provide process cooling, district cooling, air conditioning cooling, power plant cooling, or other cooling needs. In some embodiments, it may be desirable to harness or exploit the potentially sub-ambient temperature of low density liquid or high density liquid or both displaced from a lower elevation reservoir for power generation. Low density liquid or high density liquid or both displaced from a lower elevation reservoir may be heat exchanged with a process harnessing or exploiting said potentially sub-ambient temperature before, during, or after, or a combination thereof storing said low density liquid or high density liquid or both in a higher elevation reservoir.

- For example, a lower elevation reservoir may be located underground in a region where the temperature is substantially different from the temperature of the region of the higher elevation reservoir. For example, the temperature surrounding or adjacent a lower elevation reservoir may be greater than 10 degrees Celsius, or 20 degrees Celsius, or 30 degrees Celsius, or 40 degrees Celsius, or 50 degrees Celsius and the temperature surrounding or adjacent a higher elevation reservoir may be less than 0 degrees Celsius, or less than 10 degrees Celsius, or less than 20 degrees Celsius, or less than 30 degrees Celsius, or less than 40 degrees Celsius, or less than 50 degrees Celsius. In some embodiments, it may be desirable to harness or exploit the potentially higher than ambient temperature of low density liquid or high density liquid or both displaced from a lower elevation reservoir for district heating, process heating, or other heating needs. In some embodiments, it may be desirable to harness or exploit the potentially higher than ambient temperature of low density liquid or high density liquid or both displaced from a lower

elevation reservoir for power generation. Low density liquid or high density liquid or both displaced from a lower elevation reservoir may be heat exchanged with a process harnessing or exploiting said potentially higher than ambient temperature before, during, or after, or a combination thereof storing said low density liquid or high density liquid or both in a higher elevation reservoir.

[0530] In some embodiments, the low density or high density liquid or both may comprise a thermal storage medium. The large mass or thermal mass of liquid stored in some embodiments may be advantageous for use as or dual use as a thermal storage medium or a temperature buffer or both. For example, the low density liquid or high density liquid or both may be employed as a medium for cooling thermal storage, or heating thermal storage, or cooling, or heating, or heat transfer in an HVAC, or district heating system, or district cooling system, or process cooling, or process heating, or temperature stabilization, or a combination thereof.

[0531] In some embodiments, it may be desirable to employ a non-hydrate forming low density liquid. A non-hydrate forming low density liquid may comprise a liquid which does not form solid hydrates or clathrates in the presence of water under pressure. It may be advantageous to employ non-hydrate forming low density liquid as the low density liquid to enable, for example, direct contact between water and the low density liquid. For example, a non-hydrate forming low density liquid and/or direct contact between water and low density liquid may prevent or minimize the need to for a mechanical pressure exchange barrier, such as a piston, or floating separator, or bladder, which may enable longer system lifespan, lower costs, and less mechanical moving parts. For example, a non-hydrate forming low density liquid may enable direct contact pressure exchange with subsea seawater, which may reduce capital cost, reduce complexity, increase round trip efficiency, or increase system longevity, or a combination thereof. For example, in some embodiments, a non-hydrate forming low density liquid may enable direct contact of the low density liquid with an aqueous high density liquid, which may include, but are not limited to, high density liquids comprising water, or high density liquids comprising water and a density enhancer or a density enhancing reagent, or combination thereof.

[0532] In some embodiments, a portion of a low density liquid may dissolve in a high density liquid. In some embodiments, a portion of a low density liquid may dissolve in a high density liquid, even if said low density liquid is sparingly soluble or practically insoluble in said high density liquid. In some embodiments where high density liquid is displaced by low density liquid in a lower elevation reservoir, and said displaced high density liquid is transferred to a high density liquid higher elevation reservoir, low density liquid dissolved in high density liquid may form a

low density liquid vapor pressure. If desired, said low density liquid or low density liquid vapor or low density liquid vapor pressure or a combination thereof may be removed or recovered before, during, or after, or a combination thereof storage of a high density liquid in a higher elevation high density liquid reservoir. For example, said low density liquid vapor from a high density liquid may undergo a compression, or cooling, or liquefaction, or combination thereof process, forming liquid phase low density liquid and / or said liquid phase low density liquid to a higher elevation low density liquid reservoir.

[0533] Notes

- **Note:** In some embodiments, the thermal storage media and the heat transfer media may comprise the same material or a different material. For example, in some embodiments, the thermal storage media and the heat transfer media may both comprise a liquid or a liquid-liquid phase transition liquid or both. For example, in some embodiments, the thermal storage media may comprise a solid-liquid phase transition material, or a solid-solid phase transition material, or a solid-liquid slurry or a combination thereof, and/or the heat transfer media may comprise a liquid phase material, or a liquid-liquid phase transition material, or a gas-liquid phase transition material, or a solid-liquid phase transition material, or a solid-liquid slurry, or a combination thereof.
- **Note:** Water may be provided as an example liquid. For example, water may be provided as an example higher density liquid. Other higher density liquid may be employed instead of or in addition to water.
- **Note:** When no more power needs to be stored, a low density liquid pump may stop pumping. To prevent low density liquid from unintentionally flowing back into a low density liquid pump, one or more valves may be closed. A valve may be near the pump or near the lower elevation reservoir or both. Alternatively or additionally, a valve in contact with the high density liquid may be employed to prevent additional high density liquid from flowing into the lower elevation reservoir. A valve in contact with the high density liquid may be located near the lower elevation reservoir.
- **Note:** In some embodiments, the high density liquid may comprise a solid-liquid slurry, or an emulsion, or a dispersion, or a pumpable solid, or a combination thereof. For example, the high density liquid may comprise a dispersion of high density nanoparticles in a solid. For example, the high density liquid may comprise a solid-liquid mixture comprising a nanoparticle comprising a solid suspended in a liquid. For example, the high density liquid may comprise a ferrofluid. For example, the high density liquid may

comprise a solids coated with surfactants to inhibit clumping or to enable the formation of a suspension in a liquid. For example, the high density liquid may comprise a solids coated with surfactants to inhibit clumping or to enable the formation of a suspension in a liquid, such as an organic solvent or water or both. For example, the high density liquid may comprise a colloidal liquid. For example, the high density liquid may comprise nanoscale ferromagnetic, or ferrimagnetic, particles suspended in a carrier fluid, such as an organic solvent or water. For example, the high density liquid may comprise nanoscale particles suspended in a carrier fluid, such as an organic solvent or water. For example, the high density liquid may comprise solid particles suspended in a liquid by Brownian motion. In some embodiments, a ferrofluid or a magnetic fluid may be employed as a high density liquid or as a low density liquid or both and electricity may be generated by the ferrofluid or magnetic fluid passing over magnets and / or a coils. For example, the high density liquid may comprise nanoscale solid particles suspended in a carrier fluid, such as an organic solvent or water. For example, the high density liquid may comprise a slurry of a solid and a liquid. For example, the high density liquid may comprise a slurry of a solid and a liquid wherein turbulent flow, or surfactants, or Brownian motion, or a combination thereof enables the solid to remain suspended in the liquid.

- **Note:** In some embodiments, the low density liquid may comprise a solid-liquid slurry, or an emulsion, or a dispersion, or a pumpable solid, or a combination thereof. For example, in some embodiments, the low density liquid may comprise pumpable ice. For example, in some embodiments, the low density liquid may comprise a mixture of low density nanoparticles and a solvent, such as water or an organic solvent or an inorganic solvent or a combination thereof.

[0534] Notes:

- Some embodiments may be configured with a lower elevation reservoir located underground
 - No hydrate formation with non-hydrate forming low density liquids
 - Air, specifically nitrogen in the air, forms solid hydrates with water at elevated pressures (pressures greater than 30 bar depending on the temperature)
 - Non-hydrate forming low density liquids do not form solid hydrates with water regardless of the pressure, enabling higher energy density energy storage system

- In configuration with water and low density liquid in closed structure, mechanically isolated from ocean. In said configuration, water or other higher density liquid may be displaced into a pipe interconnected to a higher elevation reservoir.
- Water or higher density liquid may be in direct contact with the low density liquid. Said direct contact may occur, for example, at a liquid-liquid interface in the lower elevation reservoir.
- Said low density liquid may comprise a liquid with a density less than said high density liquid.
- Allowing low density liquid to be displaced by higher density liquid may involve opening one or more valves.
- A pump may function also as a generator. For example, in some embodiments, the pump and generate may comprise the same unit. For example, a pump / generator may comprise a hydraulic power recovery turbine or HPRT.
- Cold low density liquid may undergo further cooling before, during, or after transferring into a refrigerated or cooled higher elevation low density liquid reservoir.
- It may be desirable for said water or high density liquid to possess a similar density to the density of the water or other liquid medium surrounding the lower elevation tank
- Said low density liquid may be practically insoluble in water or the high density liquid or may possess a limited solubility in water or other high density liquid.
- Said low density liquid may comprise a liquid and may comprise a non-hydrate forming low density liquid. Some gases and liquids form hydrates, some known as clathrates, with water under high pressures and relatively low temperatures. A non-hydrate forming low density liquid may comprise a low-density liquid with a non-hydrate or non-clathrate forming molecular structure or a molecular weight too large for hydrate formation or a combination thereof. For example, including, but not limited to, one or more or a combination of the following:
 - Normal Butane (n-Butane) is a non-hydrate forming molecule. In *Calorimetric investigation of hydrates of pure isobutane and iso- and normal butane mixtures*, Buleiko et al states “the experimental measurements resulting from our work have shown conclusively that normal butane does not form hydrate in the area of research and it behaves like a nonhydrate former.” Buleiko et al evaluated “the possibility of normal butane hydrate formation... within a temperature range from 78 to 280 K and at pressure up to 15 MPa.” 15 MPa is 150 bar pressure.

- Butane, Pentane, Hexane, Heptane, Octane, Nonane
 - Hydrocarbons
 - Hydrocarbon mixtures
 - Oils
 - Organic compounds
 - Large molecular weight organic compounds
 - Diesel
- In some embodiments, the low density liquid may be soluble in water or may be a hydrate former or a combination thereof.
 - Some embodiments employing a low density liquid soluble in water or a hydrate forming low density liquid or a combination thereof may employ a barrier between the water and the water soluble or hydrate forming low density liquid. Said barrier may comprise, including, but not limited to, a floating barrier, a bladder, a bladder tank, a mutually insoluble liquid at the liquid-liquid interface, a piston, a mechanical exchange, a hydraulic pressure exchange, or a combination thereof.
 - Some embodiments employing a low density liquid soluble in water or a hydrate forming low density liquid or a combination thereof may employ a non-water higher density liquid.
 - Some embodiments employing a low density liquid soluble in water or a hydrate forming low density liquid or a combination thereof may employ water with hydrate formation inhibitors. Hydrate formation inhibitors are known in the art in the oil & gas industry. Hydrate formation inhibitors may include, but are not limited to, propylene glycol, methanol, ethylene glycol, alcohols, salts or a combination thereof.
 - Some embodiments employing a low density liquid soluble in water or other high density liquid may operate with a high density liquid containing saturated concentrations of dissolved liquid. Employing a high density liquid saturated with low density liquid may only be possible in embodiments employing low density liquids with limited solubility or partial miscibility in a high density liquid.
 - Some embodiments employing a low density liquid soluble in water or other high density liquid may employ solubility inhibitors, which may reduce or inhibit to

the solubility of low density liquid in high density liquid compared to the solubility of low density liquid in high density liquid without the presence of said solubility inhibitors. Solubility inhibitors may be dissolved in the low density liquid, the high density liquid, or both.

- Some embodiments employing a hydrate former low density liquid may employ hydrate formation inhibitors. Hydrate formation inhibitors may be dissolved in the low density liquid, the high density liquid, or both.
- Some embodiments employing a low density liquid soluble in water or other high density liquid may employ a barrier between the low density liquid and high density liquid, in, for example, a lower elevation reservoir. For example, if the low density liquid is liquid ammonia, or water soluble alcohols, or a combination thereof and water is the high density liquid, a barrier between the low density liquid and high density liquid may be required.
- Water or higher density liquid may comprise additives to provide certain advantageous properties. Additives with advantageous properties may include, but are not limited to, one or more or a combination of the following:
 - Anti-foulants
 - Anti-scalants
 - Corrosion inhibitors
 - Freezing point depressants
 - Density adjusters
 - Degradation inhibitors
 - Hydrate formation inhibitors
 - Viscosity reducers
 - Oxygen scavengers
 - Tracer or tracer chemicals, which may include, but are not limited to, chemicals which facilitate the ability to trace leaks (if a leak were to arise)
- Low density liquid may comprise additives to provide certain advantageous properties. Additives with advantageous properties may include, but are not limited to, one or more or a combination of the following:
 - Anti-foulants
 - Anti-scalants
 - Corrosion inhibitors

- Freezing point depressants
 - Density adjusters
 - Degradation inhibitors
 - Hydrate formation inhibitors
 - Viscosity reducers
 - Oxygen scavengers
 - Tracer or tracer chemicals, which may include, but are not limited to, chemicals which enable the ability to trace leaks or identify leaks if a leak were to arise
- Propane is a liquid at -44°F at atmospheric pressure
- Butane is a liquid at 30.2°F or -1°C at atmospheric pressure
- Heat exchanging with the low density liquid may occur after the pump or before the generator
- Heat exchanging with the low density liquid may occur before the pump or after the generator
- In some embodiments, the low density liquid may possess a low boiling point. A low boiling point may comprise a boiling within 10°K of a temperature feasibly achieved under ambient outdoor temperature conditions or temperatures potentially reached on a surface exposed to the sun. For example, a boiling point less than or equal to, 30°C, or 35°C, or 40°C, or 45°C, or 50°C, or 55°C, or 60°C or a combination thereof at atmospheric pressure may comprise a low boiling point.
- Embodiments employing low boiling point low density liquids may employ one or more or a combination of systems and methods to ensure safe liquid handling and storage.
 - For example, in embodiments where a higher elevation reservoir is located underwater, it may be desirable to place said higher elevation reservoir at a water depth where the hydrostatic pressure surrounding or adjacent to said higher elevation reservoir is equal to or greater than the vapor pressure of the low density liquid.
 - For example, in embodiments where the pressure of air or water surrounding or adjacent to a higher elevation reservoir is at a pressure less than the vapor pressure of the low density liquid under ambient outdoor temperature conditions, it may be desirable to employ a pressure resistant tank or pressurized tank or ASME pressurized tank or a combination thereof.

- For example, in embodiments where the pressure of air or water surrounding or adjacent to a higher elevation reservoir is at a pressure less than the vapor pressure of the low density liquid under ambient outdoor temperature conditions, it may be desirable to cool the low density liquid to reduce the vapor pressure of the low density liquid.
 - For example, the low density liquid may be cooled to a temperature at or below the boiling point of low density liquid at atmospheric pressure.
 - For example, the low density liquid may be cooled to a temperature at or below the boiling point of low density liquid at a desired pressure
 - For example, the low density liquid may be cooled to a temperature such that the vapor pressure of the low density liquid is suitable for storage in a desired tank.
 - For example, the temperature of the low density liquid within, for example, an insulated tank or a refrigerated tank or temperature controlled tank or a tank or a combination thereof may be maintained at a desired temperature range.
- A refrigerated, or temperature controlled, or cooled tank may employ one or more or a combination of methods for thermal management. For example, said thermal management methods may include, but are not limited to, one or more or a combination of the following:
 - Refrigeration
 - Chiller
 - Vapor compression refrigeration cycle
 - Absorption based refrigeration cycle
 - Evaporative cooling
 - Water-based evaporative cooling
 - Cooling due to the boiling of low density liquid. The resulting vapors may be referred to as off-gases.
 - It may be desirable to compress, liquid, or otherwise reuse or recirculate said off-gases.
 - It may be desirable to use said off-gases for fuel or other use
 - Cooling
 - Thermal storage
 - OTEC

- Cool ocean water
 - Cooling from LNG gasification, which may comprise use the endotherm of gasifying liquid natural gas to cool
 - Liquid-Liquid Phase Refrigeration Cycle
 - Gas-Gas Phase Refrigeration Cycle
 - Solid-Solid Phase Refrigeration Cycle
 - Solid-Gas Phase Refrigeration Cycle
- Butane or n-butane or normal butane may be provided as an example high vapor pressure low density liquid. Other liquids may be employed instead of or in addition to butane. Butane may also refer to solutions containing or comprising butane.
- Water may be provided as an example high density liquid or low density liquid or both. Other liquids may be employed instead of or in addition to water. Water may also refer to solutions containing or comprising water.
- Thermal storage media or medium may comprise a liquid or solid or a gas or a supercritical fluid or a combination thereof which may be employed to store heat or 'cool', or transfer heat or 'cool', or a combination thereof. Thermal storage media may comprise a phase change material, which may include, but is not limited to, a solid-liquid phase transition, a liquid-liquid phase transition, a liquid-gas phase transition, a liquid-solid phase transition, a solid-solid phase transition, a gas-gas phase transition, a chemical reaction, a reversible chemical reaction, or a combination thereof.
- Thermal storage liquid may comprise water, or an aqueous solution comprising water and a freezing point depressant, or a non-aqueous liquid, or a liquid-liquid phase transition liquid, or a combination thereof.
- Thermal storage liquid may comprise water, or an aqueous solution comprising water and a freezing point depressant. For example, thermal storage liquid may comprise a solution of water and, including, but not limited to, one or more or a combination of the following:
 - Water soluble organic, which may include, but is not limited to, one or more or a combination of the following: propylene glycol, ethylene glycol, methanol, ethanol, propanol, isopropanol, acetone, ketones, alcohols, aldehydes, glycols, glycol polymers, polymers, sugars, sugar alcohols, sugar substitutes, molasses
 - Water soluble nitrogen compound, which may include, but is not limited to, one or more or a combination of the following: ammonia, nitric acid, urea, or derivatives thereof

- Ionic compound, which may include, but is not limited to, one or more or a combination of the following: sodium chloride, calcium chloride, ammonium salts, sodium salt, calcium salt, magnesium salt, potassium salt, sea salt, alkali metal salt, alkaline earth metal salt, transition metal salt, chloride salt, sulfate salt, sulfite salt, carbonate salt, bicarbonate salt, surfactant
 - Ionic-liquid + water solutions
 - Acids
 - Bases
 - Water soluble gas
 - Water soluble sulfur compound, which may include, but is not limited to, organosulfur compounds
- Thermal storage heat exchange may be employed to reduce cooling energy requirements.
- Thermal storage heat exchange may be employed to recover 'cold' stored in the specific heat capacity of liquid butane.
- Thermal storage medium may be stored in a one or more tanks.
- Thermal storage medium may be stored in a tank with a temperature gradient. For example, colder thermal storage liquid forms a temperature layer and warmer thermal storage liquid forms another temperature layer.
- Thermal storage medium may be stored in two or more tanks, with at least one tank for 'warm' liquid and at least one tank for 'cold' liquid.
- Before or during charging, liquid butane may be heat exchanged with 'warm' thermal storage medium, forming 'cold' thermal storage medium and forming 'warm' butane. Said heat exchange may be conducted when the butane is at a pressure greater than or equal to the vapor pressure of the butane. For example, said heat exchange may be conducted after or during a liquid butane pumping stage or pressurization stage. For example, the presently described step may be conducted before or while butane is transferred from a higher elevation reservoir to a lower elevation reservoir, which may be required when the present energy storage device is storing electricity or undergoing 'charging'.
- Before or during discharging, liquid butane may be heat exchanged with 'cold' thermal storage medium, cooling the liquid butane to near at or below the boiling point of butane at atmospheric pressure (or other desired pressure) and forming 'warm' thermal storage liquid. For example, said heat exchange may be conducted before or during a liquid butane hydraulic power generating stage or depressurization stage. For example, the presently

described step may be conducted before or while or after butane is transferred from a lower elevation reservoir to a higher elevation reservoir, which may be required when the present energy storage device is generating electricity or undergoing ‘discharging’.

- During installation and / or project setup, low density liquid may be added to a system using one or more or a combination of processes.
 - For example, low density liquid may be added or removed by connecting a flowline from an LPG or other hydrocarbon or low density liquid transport vessel to an interconnection point on a low density liquid subsea pipeline in the energy storage system.
 - For example, low density liquid may be added or removed by connecting an LPG or other hydrocarbon or low density liquid transport vessel to a disconnectable buoy. Said disconnectable buoy may be connected to one or more points of a low density liquid tank or subsea pipeline or a combination thereof.
 - For example, low density liquid may be added or removed by means of low density liquid transferred from a pipeline
 - For example, low density liquid may be added or removed by means of low density liquid transferred from rail cars
 - For example, low density liquid may be added or removed by means of low density liquid transferred from tanker trucks, or bullet tanks, or a combination thereof
 - If a low density liquid reservoir is refrigerated or cooled, low density liquid added may be cooled or refrigerated before, during, or after the addition of low density liquid to a refrigerated or cooled low density liquid reservoir.
- Liquid n-Butane specific heat capacity: 2.275 J/g°C
- ‘Cold’ thermal storage medium may comprise thermal storage medium at or below the boiling point temperature of the low density liquid at 1 bar pressure (or another desired pressure range)
- ‘Cold’ thermal storage medium may be stored in insulated tanks
- ‘Cold’ thermal storage medium may be maintained at a sufficiently cold temperature with thermal management. Said thermal management may comprise refrigeration or other cooling method when the temperature of the thermal storage medium exceeds a certain temperature or temperature range or when desired. Sufficiently cold temperature thermal storage medium may comprise at temperature, which when heat exchanged with ‘warm’

low density liquid, the resulting 'cooled' low density liquid possesses a vapor pressure less than or equal to the design pressure rating of a higher elevation tank. In some embodiments, sufficiently cold temperature thermal storage medium may comprise at temperature, which when heat exchanged with 'warm' low density liquid, the resulting 'cooled' low density liquid is at a temperature less than the temperature of 'warm' low density liquid. In some embodiments, said 'cooled' low density liquid may possess a vapor pressure less than or equal to the pressure rating of a higher elevation storage reservoir and may be transferred into said higher elevation storage reservoir. In some embodiments, said 'cooled' low density liquid may possess a vapor pressure greater than or equal to the pressure rating of a higher elevation storage reservoir and may undergo further cooling before being transferred into said higher elevation storage reservoir. In some embodiments, said 'cooled' low density liquid may possess a vapor pressure less than or equal to the pressure rating of a higher elevation storage reservoir and may undergo further cooling before being transferred into said higher elevation storage reservoir.

- Thermal storage medium heat exchange with low density liquid may occur before or after or both a pump and / or generator step.
- A refrigerated or cooled higher elevation reservoir may require more parasitic cooling energy consumption when the present energy storage system is partially or fully discharged. A partially or fully discharged state may involve when the higher elevation or on land or above water storage reservoir is partially or completely full of low density liquid.
- Some embodiments may involve a closed system where displaced higher density liquid is transferred from a lower reservoir to a higher elevation reservoir. In some embodiments, a pipe which transfers higher density liquid between a lower and higher elevation reservoir may be surrounded by or immersed in liquid with similar or equal density. If, for example, or said pipe immersed in or surrounded by or adjacent to liquid with similar or equal density, said higher density liquid pipe may possess a pressure inside the pipe which is near or equal to the hydrostatic pressure outside the pipe. If, for example, said pipe is immersed in or surrounded by or adjacent to liquid with similar or equal density, said higher density liquid pipe may be constructed using pipe requiring less pressure resistance than the low density liquid pipe. Said pipe requiring less pressure resistance may be lower cost or larger diameter or both compared to the pipe or pipes employed for low density liquid.
- A refrigeration system for cooling a low density liquid storage reservoir employ backup generators. Said backup generators may be utilized to power cooling or refrigeration

equipment in the event of an emergency. Said backup generators, for example, may be used when the energy storage system is fully discharged and there no other sources of electricity. Said backup generators may, for example, be powered by low density liquid, such as, including, but not limited to, butane or other low density liquid or gas-liquid fuel. Said backup generators may be powered by other fuel sources if desired.

- Power smoothing or immediate response may employ lithium ion batteries, batteries, flywheels, capacitors, supercapacitors, or other energy storage systems if desired.
- Systems, or methods, or controls may be employed to minimize or mitigate the potential strength of hydraulic pressure waves or ‘hydraulic hammer’, which may have potential to occur during changes in liquid flow rate or liquid pressure or a combination thereof. Hydraulic hammer or hydraulic pressure wave mitigation measures may be known in the art, and may include, but are not limited to, gradual flow rate adjustment, startup procedures, shutdown procedures, water towers, surge tanks, hydropneumatics shock absorbers, hydraulic shock absorbers, expansion tanks, pumping bypass, pumping flywheel, or a combination thereof.
- Refrigerated or cooled tank for storing low boiling point low density liquid may be similar or the same as refrigerated tanks employed in the art for, for example, including, but not limited to, one or more or a combination of the following: LPG terminals, propane storage, butane storage, ammonia storage, NGL storage, LNG storage, or a combination thereof.
- Subsea tank construction material may comprise including, but not limited to, one or more or a combination of the following: Metal, Steel, Aluminum, Concrete, Pre-cast concrete, Plastic, Coated polyethylene, Polypropylene, Composite, Fiberglass, rubber, fabric, aggregate.
- Low density liquid may experience changes in density with temperature and pressure
- Due to the relatively low temperature of deep sea ocean water (generally about 0 – 3°C), during discharging, the low density liquid may return to the higher elevation reservoir at a temperature less than the surrounding ambient temperature. If the low density liquid may return to the higher elevation reservoir at a temperature less than the surrounding ambient temperature due to cooling occurring in the deep ocean, the low density liquid may require less cooling or heat removal than is available in the thermal storage, which may further reduce potential parasitic energy demand associated with refrigerated or cooled low density liquid storage.

- Seawater may be employed as a thermal storage liquid. Seawater may possess a freezing point of about -2 degrees Celsius.
- Desalination brine or reverse osmosis brine may be employed as a thermal storage liquid.
- Additives may be added to the thermal storage liquid. Additives may include, but are not limited to, one or more or a combination of the following: inhibitors, oxygen scavengers, freezing point depressants, other additives described herein, other additives in the art.
- The present invention may contain pumps, sensors, controls, pipes, valves, and / or other equipment or materials which may not be shown in figures or described herein.
- Thermal storage reservoirs may comprise rigid tanks, or bladder tanks, or a combination thereof.
- Higher elevation reservoirs and / or lower elevation reservoirs may comprise rigid tanks, or bladder tanks, or a combination thereof.
- Thermal storage reservoirs may contain a floating or solid-material or liquid material or a combination thereof barrier to separate or minimize mixing of 'warm' and 'cold' thermal storage liquid or thermal storage medium.
- Tanks and reservoirs may comprise tanks and reservoirs known in the art for storing liquid, solids, gases, gas-liquid, or a combination thereof. For example, tanks and reservoirs may comprise, including, but not limited to, one or more or a combination of the following: ASME pressurized tank, semi-pressurized tank, atmospheric pressure tank, equilibrium pressure tank, floating roof tank, Horton sphere, bullet tank, steel tank, cement tank, fiberglass tank, composite tank, plastic tank, aluminum tank, stainless steel tank, titanium tank, metal tank, glass tank, ceramic tank, wood tank, bladder tank, rigid tank, piston tank, refrigerated tank, cooled tank, open air tank, open air pit, open air pond, liner pond, flexible tank, modular tank, subsea tank, pressure equilibrium tank, hybrid tank, anchored tank, density neutral tank, tank with ballast, tank with support structure, seafloor tank, underground tank, insulated tank, mobile tank, non-mobile tank, cylinder tank, open bottom tank, open port tank, tank with port and valve, close system tank, open system tank.

Example Figure Descriptions

[0535] Figure 120: A process for energy storage which stores electricity by displacing a high density liquid with a low density liquid. Energy may be stored in the gravitational potential energy difference between a high density liquid and a low density liquid between two different elevations. The embodiment shown in the present figure may employ a higher elevation reservoir and a lower elevation reservoir, each which may be designed to store both high density liquid and low density

liquid. Under conditions where the system stores no gravitational potential energy, the higher elevation reservoir may store low density liquid and the lower elevation reservoir may store high density liquid. Energy may be stored when at least a portion of low density liquid has displaced at least a portion of high density liquid in a lower elevation reservoir. In the embodiment shown in the present figure, the volume of liquid in both the higher elevation reservoir and the lower elevation reservoir may, if desired, remain relatively constant because the volume of liquid entering a reservoir may be equal to the volume of liquid exiting said reservoir. For example, generally if a volume of low density liquid is pumped from a higher elevation reservoir into a lower elevation reservoir, about an equal volume of high density liquid may be displaced from the lower elevation reservoir and transferred into the higher elevation reservoir. The present figure shows a higher elevation reservoir on land and a lower elevation reservoir under water. The present figure shows an energy storage system at a steady nearly fully ‘discharged’ state.

[0536] Figure 121: Similar to Figure 120, except the present figure shows an energy storage system storing energy or electricity or ‘charging’.

[0537] Figure 122: Similar to Figure 120, except the present figure shows an energy storage system at a steady nearly full ‘charged’ state.

[0538] Figure 123: Similar to Figure 120, except the present figure shows an energy storage system at generating energy or generating electricity, or ‘discharging.’

[0539] Figure 124: A process for energy storage which stores electricity by displacing a high density liquid with a low density liquid. Energy may be stored in the gravitational potential energy difference between a high density liquid and a low density liquid between two different elevations. The embodiment shown in the present figure may employ a higher elevation reservoir and a lower elevation reservoir, each which may be designed to store both high density liquid and low density liquid. Under conditions where the system stores no gravitational potential energy, the higher elevation reservoir may comprise low density liquid and the lower elevation reservoir may comprise high density liquid. Energy may be stored when at least a portion of low density liquid has displaced at least a portion of high density liquid in a lower elevation reservoir. In the embodiment shown in the present figure, the volume of liquid in both the higher elevation reservoir and the lower elevation reservoir may, if desired, remain relatively constant because the volume of liquid entering a reservoir may be equal to the volume of liquid exiting said reservoir. For example, if a volume of low density liquid is pumped from a higher elevation reservoir into a lower elevation reservoir, an equal volume of high density liquid may be displaced from the lower elevation reservoir and transferred into the higher elevation reservoir. The present figure shows a

higher elevation reservoir on a floating structure and a lower elevation reservoir underwater. The present figure shows an energy storage system at a steady nearly fully ‘discharged’ state.

[0540] Figure 125: Similar to Figure 124, except the present figure shows an energy storage system storing energy or electricity or ‘charging’.

[0541] Figure 126: Similar to Figure 124, except the present figure shows an energy storage system at a steady nearly full ‘charged’ state.

[0542] Figure 127: Similar to Figure 124, except the present figure shows an energy storage system generating energy or generating electricity, or ‘discharging.’

[0543] Figure 128: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. Energy may be stored in the gravitational potential energy difference between a high density liquid and a low density liquid between two different elevations. The embodiment shown in the present figure may employ a higher elevation reservoir and a lower elevation reservoir, each which may be designed to store both high density liquid and low density liquid. The embodiment shown in the present figure may operate with a different temperature in the higher elevation reservoir than the lower elevation reservoir. For example, the higher elevation reservoir may be at a lower temperature than the lower elevation reservoir. The embodiment shown in the present figure may efficiently enable the higher elevation reservoir to store liquid at a different temperature than the lower elevation reservoir by employing, for example, low density liquid and high density liquid heat exchange and / or heat exchange with supplemental thermal storage. Due to, for example, the difference in heat capacity between low density liquid and high density liquid, a portion of the high density liquid may be heat exchanged with low density liquid and another portion of the high density liquid may be heat exchanged with supplemental thermal storage. The present figure shows the present embodiment with a thermal storage system comprising a ‘cold’ thermal storage reservoir and a ‘warm’ thermal storage reservoir. The present figure shows an energy storage system storing energy or electricity or ‘charging’.

[0544] Figure 129: Similar to Figure 128, except the present figure shows an energy storage system generating energy or generating electricity, or ‘discharging.’

[0545] Figure 130: Similar to Figure 128, except the present figure shows the present embodiment with a thermal storage system comprising a reservoir comprising both ‘warm’ and ‘cold’ thermal storage, which may be separate within the tank due to, including, but not limited to, one or more or a combination of the following: a temperature gradient, or bladder, or barrier, or other separator.

[0546] Figure 131: Similar to Figure 128, except the present figure shows the present embodiment with a thermal storage system comprising a reservoir comprising both ‘warm’ and ‘cold’ thermal storage, which may be separate within the tank due to, including, but not limited to, one or more or a combination of the following: a temperature gradient, or bladder, or barrier, or other separator.

[0547] Figure 132: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. Energy may be stored in the gravitational potential energy difference between a high density liquid and a low density liquid between two different elevations. The embodiment shown in the present figure may employ a higher elevation reservoir and a lower elevation reservoir, each which may be designed to store both high density liquid and low density liquid. The embodiment shown in the present figure may operate with a different temperature in the higher elevation reservoir than the lower elevation reservoir. For example, the higher elevation reservoir may be at a lower temperature than the lower elevation reservoir. The embodiment shown in the present figure may efficiently enable the higher elevation reservoir to store liquid at a different temperature than the lower elevation reservoir by employing a ‘warm’ high density liquid storage reservoir, a low density liquid – high density liquid heat exchange, and a ‘cold’ high density liquid storage reservoir. Due to, for example, the difference in heat capacity between low density liquid and high density liquid, a portion of the high density liquid may be heat exchanged with low density liquid and another portion of the high density liquid may be stored in a ‘warm’ high density liquid storage reservoir. The embodiment shown in the present figure may employ a ‘cold’ high density liquid storage reservoir. ‘Cold’ high density liquid transferred to and from a higher elevation reservoir designed to store both high density liquid and low density liquid may be transferred to and from said ‘cold’ high density liquid storage reservoir. The present figure shows an energy storage system storing energy or electricity or ‘charging’.

[0548] Figure 133: Similar to Figure 132, except the present figure shows an energy storage system generating energy or generating electricity, or ‘discharging.’

[0549] Figure 134: Similar to Figure 132, except the present figure shows an energy storage system with a cooling system or thermal management system applying cooling or other thermal management to both a ‘cold’ high density liquid storage reservoir and a reservoir designed to store both low density liquid and high density liquid.

[0550] Figure 135: Similar to Figure 134, except the present figure shows an energy storage system generating energy or generating electricity, or ‘discharging.’

[0551] Figure 136: Similar to Figure 134, except showing example calculations for flow rate.

[0552] Figure 137: Similar to Figure 135, except showing example calculations for flow rate.

[0553] Figure 138: A process for energy storage which stores electricity by displacing a higher density liquid with a lower density liquid. Energy may be stored in the gravitational potential energy difference between a high density liquid and a low density liquid between two or more reservoirs at least two or more different elevations. The embodiment shown in the present figure may employ a higher elevation reservoir and a lower elevation reservoir, each which may be designed to store both high density liquid and low density liquid. The embodiment shown in the present figure may operate with a similar temperature in the higher elevation reservoir as the temperature in the lower elevation reservoir. The embodiment shown in the present figure may operate with a higher elevation reservoir with a different temperature than the ambient temperature adjacent to or surrounding said higher elevation reservoir, or a relatively stable temperature, or a combination thereof. The embodiment shown in the present figure may efficiently enable the higher elevation reservoir to store liquid at a different temperature than the ambient temperature adjacent to or surrounding said higher elevation reservoir by employing low density liquid – high density liquid heat exchange and by employing heat exchange and / or cooling with ‘cold’ ocean water from the deep ocean (‘cold deep ocean water’, which may be represented by ‘CW’ in Figure 138). The present figure shows an energy storage system storing energy or electricity or ‘charging’.

[0554] Figure 139: Similar to Figure 138, except shows an energy storage system generating energy or generating electricity, or ‘discharging’.

Example Figure Keys

[0555] Figures 120 – 123:

Label	Description
1	Higher elevation reservoir designed to store both low density liquid and high density liquid. May comprise one or more storage tanks. May be atmospheric pressure, or semi-pressurized, or pressurized, or a combination thereof. May be semi-refrigerated or fully refrigerated, or non-refrigerated, or a combination thereof.
2	A lower elevation reservoir designed to store both low density liquid and high density liquid.
3	Pipe transferring low density liquid between a pump / generator and a lower elevation reservoir.
4	A pump and / or generator.
5	A valve.
6	Pipe transferring high density liquid between a lower elevation reservoir and a higher elevation reservoir.
Ocean	May comprise a water body, such as an ocean or lake. May represent a body of liquid. May represent a body of solid. May represent a combination thereof.

Land	May comprise land or solid surface or a combination thereof.
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[0556] Figures 124 – 127:

Label	Description
1	Higher elevation reservoir designed to store both low density liquid and high density liquid. May comprise one or more storage tanks. May be atmospheric pressure, or semi-pressurized, or pressurized, or a combination thereof. May be semi-refrigerated or fully refrigerated, or non-refrigerated, or a combination thereof.
2	A lower elevation reservoir designed to store both low density liquid and high density liquid.
3	Pipe transferring low density liquid between a pump / generator and a lower elevation reservoir.
4	A pump and / or generator.
5	Pipe transferring high density liquid between a lower elevation reservoir and a higher elevation reservoir.
6	A floating structure which may be employed to contain at least a portion of higher elevation parts or higher elevation region. May comprise an FSO, or FSU, or platform, or ship, or converted structure, or a custom structure, a moored structure, or a stable structure, or a buoyant structure, or a combination thereof.
Ocean	May comprise a water body, such as an ocean or lake. May represent a body of liquid. May represent a body of solid. May represent a combination thereof.
Land	May comprise land or solid surface or a combination thereof.

[0557] Figure 128 and Figure 129:

Label	Description
1	Higher elevation reservoir designed to store both low density liquid and high density liquid. May comprise one or more storage tanks. May be atmospheric pressure, or semi-pressurized, or pressurized, or a combination thereof. May be semi-refrigerated or fully refrigerated, or non-refrigerated, or a combination thereof.
2	Pipe transferring low density liquid between a low density liquid – high density liquid heat exchanger and a higher elevation reservoir.
3	A low density liquid – high density liquid heat exchanger. May represent a countercurrent heat exchanger.
4	Pipe transferring low density liquid between a low density liquid – high density liquid heat exchanger and a pump / generator.
5	A pump and / or generator.
6	Pipe transferring low density liquid between higher elevation region and lower elevation region.
7	Lower elevation reservoir designed to store both low density liquid and high density liquid.
8	A pipe transferring high density liquid between a lower elevation reservoir and higher elevation reservoir.
9	A high density liquid flow splitter during storing energy or ‘charging’ (flow merger during generating electricity or ‘discharging’).

10	A liquid stream of high density liquid with a total heat capacity about the same as the heat capacity of low density liquid and may represent high density liquid transferred between a flow splitter and a low density liquid – high density liquid heat exchanger
11	A high density liquid stream after heat exchange with low density liquid and may represent high density liquid transferred between low density liquid – high density liquid heat exchanger and flow merger.
12	A liquid stream of high density liquid transferred between a flow splitter and a high density liquid – supplemental thermal storage heat exchanger.
13	A high density liquid – supplemental thermal storage heat exchanger.
14	A high density liquid stream after heat exchange with supplemental thermal storage and may represent high density liquid transferred between a high density liquid – supplemental thermal storage heat exchanger and a flow merger.
15	‘15’ may represent a stream merger or flow merger (although may represent a flow splitter during generating electricity or ‘discharging’).
16	‘16’ may represent high density liquid transferred between a flow merger and a higher elevation reservoir designed to store both low density liquid and high density liquid.
17	‘17’ may represent a ‘warm’ supplemental thermal storage reservoir.
18	‘18’ may represent thermal storage medium or heat transfer medium transferred between a high density liquid – supplemental thermal storage heat exchanger and a ‘warm’ supplemental thermal storage reservoir and may represent ‘warm’ thermal storage medium or heat transfer medium.
19	‘19’ may represent thermal storage medium or heat transfer medium transferred between a high density liquid – supplemental thermal storage heat exchanger and a ‘cold’ supplemental thermal storage reservoir and may represent ‘cold’ thermal storage medium or heat transfer medium.
20	‘20’ may represent a ‘cold’ supplemental thermal storage reservoir.
21	A thermal management process or cooling source or a heat sink or a chiller or a refrigeration process or a compressor or a liquefaction process or cooling process or a combination thereof. May represent a cooling source or thermal management system or a combination thereof to provide cooling or thermal management to the higher elevation reservoir, or low density liquid, or high density liquid, or a combination thereof as needed.
22	May represent any heat transfer between a cooling source or thermal management system or a combination thereof and a higher elevation reservoir or low density liquid, or high density liquid, or a combination thereof.
Higher Elevation	Label for an adjacent dashed box. Said adjacent dashed box may contain high elevation parts or higher elevation region.
Lower Elevation	Label for an adjacent dashed box. Said adjacent dashed box may contain lower elevation parts or lower elevation region.

[0558] Please note: The above figure key may define certain components in the context of a system undergoing storing power or ‘charging’. Some terms, such as ‘flow merger’, may comprise a different term or reverse application, such as ‘flow splitter’, when the system is undergoing generating power or generating electricity or ‘discharging’.

[0559] Figures 132 – 137:

Label	Description
1	Higher elevation reservoir designed to store both low density liquid and high density liquid. May comprise one or more storage tanks. May be atmospheric pressure, or semi-pressurized, or pressurized, or a combination thereof. May be semi-refrigerated or fully refrigerated, or non-refrigerated, or a combination thereof.
2	Pipe transferring low density liquid between a low density liquid – high density liquid heat exchanger and a higher elevation reservoir.
3	A low density liquid – high density liquid heat exchanger. May represent a countercurrent heat exchanger.
4	Pipe transferring low density liquid between a low density liquid – high density liquid heat exchanger and a pump / generator.
5	A pump and / or generator.
6	Pipe transferring low density liquid between higher elevation region and lower elevation region.
7	Lower elevation reservoir designed to store both low density liquid and high density liquid.
8	A pipe transferring high density liquid between a lower elevation reservoir and higher elevation reservoir.
9	A high density liquid flow splitter during storing energy or ‘charging’ (flow merger during generating electricity or ‘discharging’).
10	A liquid stream of high density liquid transferred between a flow splitter and a ‘warm’ high density liquid storage reservoir.
11	A ‘warm’ high density liquid storage reservoir.
12	A liquid stream of high density liquid with a total heat capacity about the same as the heat capacity of low density liquid and may represent high density liquid transferred between a flow splitter and a low density liquid – high density liquid heat exchanger.
13	A high density liquid stream after heat exchange with low density liquid and may represent high density liquid transferred between low density liquid – high density liquid heat exchanger and a ‘cold’ high density liquid thermal storage reservoir.
14	A ‘cold’ high density liquid thermal storage reservoir.
15	High density liquid transferred between a ‘cold’ high density liquid thermal storage reservoir and a higher elevation reservoir designed to store both low density liquid and high density liquid
21	A thermal management process or cooling source or a heat sink or a chiller or a refrigeration process or a compressor or a liquefaction process or cooling process or a combination thereof. May represent a cooling source or thermal management system or a combination thereof to provide cooling or thermal management to the higher elevation reservoir, or low density liquid, or high density liquid, or a combination thereof as needed.
22	May represent any heat transfer between a cooling source or thermal management system or a combination thereof and a higher elevation reservoir or low density liquid, or high density liquid, or a combination thereof.
Higher Elevation	Label for an adjacent dashed box. Said adjacent dashed box may contain high elevation parts or higher elevation region.

Lower Elevation	Label for an adjacent dashed box. Said adjacent dashed box may contain lower elevation parts or lower elevation region.
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[0560] Please note: The above figure key may define certain components in the context of a system undergoing storing power or ‘charging’. Some terms, such as ‘flow merger’, may comprise a different term or reverse application, such as ‘flow splitter’, when the system is undergoing generating power or generating electricity or ‘discharging’.

[0561] Figure 138 and Figure 139:

Label	Description
1	Higher elevation reservoir designed to store both low density liquid and high density liquid. May comprise one or more storage tanks. May be atmospheric pressure, or semi-pressurized, or pressurized, or a combination thereof. May be semi-refrigerated or fully refrigerated, or non-refrigerated, or a combination thereof.
2	Pipe transferring low density liquid between a low density liquid – high density liquid heat exchanger and a higher elevation reservoir.
3	A low density liquid – high density liquid heat exchanger. May represent a countercurrent heat exchanger.
4	Pipe transferring low density liquid between a low density liquid – high density liquid heat exchanger and a pump / generator.
5	A pump and / or generator.
6	Pipe transferring low density liquid between higher elevation region and lower elevation region.
7	Lower elevation reservoir designed to store both low density liquid and high density liquid.
8	A pipe transferring high density liquid between a lower elevation reservoir and higher elevation reservoir.
9	A high density liquid flow splitter during storing energy or ‘charging’ (flow merger during generating electricity or ‘discharging’).
10	A liquid stream of high density liquid with a total heat capacity about the same as the heat capacity of low density liquid and may represent high density liquid transferred between a flow splitter and a low density liquid – high density liquid heat exchanger.
11	A liquid stream of high density liquid with a total heat capacity about the same as the heat capacity of low density liquid and may represent high density liquid transferred between a low density liquid – high density liquid heat exchanger and a flow merger.
12	A liquid stream of high density liquid with a total heat capacity in excess of the total heat capacity of low density liquid. A liquid stream of high density liquid which may be transferred between a flow splitter and a high density liquid – ‘cold’ ocean water heat exchanger.
13	A high density liquid – ‘cold’ ocean water heat exchanger.
14	A liquid stream of high density liquid with a total heat capacity in excess of the total heat capacity of low density liquid. A liquid stream of high density liquid

	which may be transferred between a high density liquid – ‘cold’ ocean water heat exchanger and a flow merger.
15	A high density liquid flow merger during storing energy or ‘charging’ (flow splitter during generating electricity or ‘discharging’).
16	High density liquid transferred between a flow merger and a higher elevation reservoir designed to store both low density liquid and high density liquid.
17	Cold water supply. May comprise ‘cold’ ocean water pumped from deep ocean depths. May comprise ‘cold’ ocean water. May comprise cold water transferred between the ocean and a high density liquid – ‘cold’ ocean water heat exchanger.
18	Cold water return. May comprise cold water after providing ‘cooling’ or heat sink and returned to the source, such as ocean or evaporative cooling or a combination thereof. May comprise water transferred between a high density liquid – ‘cold’ ocean water heat exchanger and the ocean.
21	A thermal management process or cooling source or a heat sink or a chiller or a refrigeration process or a compressor or a liquefaction process or cooling process or a combination thereof. May represent a cooling source or thermal management system or a combination thereof to provide cooling or thermal management to the higher elevation reservoir, or low density liquid, or high density liquid, or a combination thereof as needed.
22	May represent any heat transfer between a cooling source or thermal management system or a combination thereof and a higher elevation reservoir or low density liquid, or high density liquid, or a combination thereof.
Higher Elevation	Label for an adjacent dashed box. Said adjacent dashed box may contain high elevation parts or higher elevation region.
Lower Elevation	Label for an adjacent dashed box. Said adjacent dashed box may contain lower elevation parts or lower elevation region.

[0562] Please note: The above figure key may define certain components in the context of a system undergoing storing power or ‘charging’. Some terms, such as ‘flow merger’, may comprise a different term or reverse application, such as ‘flow splitter’, when the system is undergoing generating power or generating electricity or ‘discharging’.

Additional Description

[0563] In some embodiments, the higher elevation and / or lower elevation reservoirs may be designed to store both low density liquid and high density liquid. Some embodiments may involve storing low density liquid and high density liquid in at least a portion of the same tanks or vessels. For example, some embodiments may involve a higher elevation reservoir designed to store both low density liquid and high density liquid, where low density liquid and high density liquid may be stored in the same tank or tanks. For example, some embodiments may involve a lower elevation reservoir designed to store both low density liquid and high density liquid, where low density liquid and high density liquid may be stored in the same tank or tanks.

[0564] In some embodiments, a tank may be designed to store both low density liquid and high density liquid. In some embodiments, the total volume of liquid stored in said tank may remain constant, while the relative volume of low density liquid and high density liquid may vary depending on the state of charge (percentage of electricity storage capacity) and / or other factors. For example, a higher elevation storage reservoir comprising at least one tank may comprise a tank which is designed to store both low density liquid and high density liquid. In the present example, if a volume of low density liquid is transferred from said tank, an equal volume of high density liquid may be transferred into said tank. Similarly, in the present example, if a volume of high density liquid is transferred from said tank, an equal volume of low density liquid may be transferred into said tank. For example, a lower elevation storage reservoir comprising at least one tank may comprise a tank which is designed to store both low density liquid and high density liquid. In the present example, if a volume of low density liquid is transferred from said tank, an equal volume of high density liquid may be transferred into said tank. Similarly, in the present example, if a volume of high density liquid is transferred from said tank, an equal volume of low density liquid may be transferred into said tank. The presently described embodiments may exhibit multiple advantages:

- For example, the presently described embodiments may enable the use of fewer tanks. A higher elevation region which employs a tank designed to store both low density liquid and high density liquid may require one half the storage capacity volume as a higher elevation region which stores high density liquid and low density liquid separately.
- For example, the presently described embodiments may enable the use of rigid and / or fixed volume structures for storage tanks. The use of rigid and / or fixed volume structures for storage tanks may be enabled by the ability of the system to store the same volume of liquid in the tank regardless of the state of charge of the energy storage tank. Compared to floating roof tanks and / or bladder type tanks, rigid or fixed volume tanks may be longer lasting, or lower cost, or require less maintenance, or possess fewer points of failure, or a combination thereof.
- For example, the presently described embodiments may enable the use of high density liquid and / or low density liquid as a thermal storage medium, which may increase energy efficiency in systems which may require a cooled or refrigerated or temperature controlled low density (and / or high density) liquid. In some embodiments, heat exchanging entering and exiting low density liquid and high density liquid may enable heat recovery and enable significantly lower cooling parasitic load. For example, in a higher elevation reservoir,

during storing electricity or ‘charging’, low density liquid may exit the higher elevation reservoir and may be heat exchanged with high density liquid before or while high density liquid enters the higher elevation reservoir. For example, in a higher elevation reservoir, during generating electricity or ‘discharging’, high density liquid may exit the higher elevation reservoir and may be heat exchanged with low density liquid before or while low density liquid enters the higher elevation reservoir.

- For example, the presently described embodiments may enable systems with floating higher elevation reservoirs to possess floating vessels which continuously contain the same volume of stored liquid, which may enable sufficiently ballasted or more stable floating higher elevation reservoirs during most or all states of charge.

[0565] In some embodiments, it may be desirable for the low density liquid and high density liquid to be in direct contact at a liquid-liquid interface within a tank. For example, it may be desirable for the low density liquid and high density liquid to be in direct contact at a liquid-liquid interface in embodiments where, including, but not limited to, one or more or a combination of the following: low density liquid is practically insoluble in high density liquid, or low density liquid is fully saturated in the high density liquid, or high density liquid is fully saturated in the low density liquid.

[0566] In some embodiments, it may be desirable for the low density liquid and high density liquid to be separate within a tank. For example, in some embodiments, it may be desirable for the low density liquid and high density liquid to be separated by a floating barrier, or a bladder, or a liner, or a pressure exchanger. For example, in some embodiments, it may be desirable for the low density liquid and high density liquid to be separated by a floating barrier, or a bladder, or a liner, or a pressure exchanger due to, including, but not limited to, one or more or a combination of the following: low density liquid is soluble in high density liquid, or low density liquid is stored at or near or below the freezing point of high density liquid, or low density liquid can form hydrates with high density liquid, or low density liquid reacts with high density liquid. In some embodiments, said separation within a tank may comprise an insulated barrier, which may enable low density liquid and high density liquid to be stored at different temperatures within the same tank. Although some embodiments involve storing low density liquid and high density liquid at the same or similar temperatures, it may be advantageous in some other embodiments to storage low density liquid and high density liquid at different temperatures. For example, storing low density liquid and high density liquid at different temperatures may be desirable, if, for example, including, but not limited to, one or more or a combination of the following: low density liquid is

stored at a temperature at or near or below the freezing point of the high density liquid or the high density liquid is stored at or near or above a temperature which may result in too high of a vapor pressure of low density liquid.

[0567] In some embodiments, low density liquid and high density liquid may be stored, at least in part, in a higher elevation reservoir and / or lower elevation reservoir designed to store both low density liquid and high density liquid. In some embodiments, storing electricity or ‘charging’ may involve transferring a low density liquid from a higher elevation reservoir into a lower elevation reservoir, which may involve displacing high density liquid from the lower elevation reservoir into the higher elevation reservoir. Similarly, in some embodiments, generating electricity or ‘discharging’ may involve transferring a high density liquid from a higher elevation reservoir into a lower elevation reservoir, which may involve displacing low density liquid from the lower elevation reservoir into the higher elevation reservoir. During charging, the volume of low density liquid entering a lower elevation reservoir may be equal to the volume of high density liquid exiting a lower elevation reservoir. During charging, the volume of high density liquid entering a higher elevation reservoir may be equal to the volume of low density liquid exiting a higher elevation reservoir. During discharging, the volume of high density liquid entering a lower elevation reservoir may be equal to the volume of low density liquid exiting a lower elevation reservoir. During discharging, the volume of low density liquid entering a higher elevation reservoir may be equal to the volume of high density liquid exiting a higher elevation reservoir. In some embodiments, one or more or a combination of reservoirs may need to be heated or cooled or both.

[0568] Heating or cooling or both may involve the low density liquid and / or high density liquid being temperature controlled or ensuring the low density liquid and / or high density liquid are within design temperature ranges within certain sections of the system. For example, in some embodiments, a higher elevation reservoir may be ‘cooled’ to ensure the temperature of low density liquid is at or below a temperature range to ensure the vapor pressure of the low density liquid is less than or equal to the design pressure of a storage tank. For example, in some embodiments, a lower elevation reservoir may be ‘heated’ to ensure the temperature of low density liquid and high density liquid is at or above a temperature range to prevent the formation of solid hydrates. ‘Cooling’ or ‘cooled’ may involve maintaining or storing the low density liquid or high density liquid or both at or below a temperature range. ‘Cooling’ or ‘cooled’ may involve maintaining or storing the low density liquid or high density liquid or both at or below the temperature of the environment outside a reservoir. ‘Heating’ or ‘heated’ may involve maintaining

or storing the low density liquid or high density liquid or both at or above a temperature range. 'Heating' or 'heated' may involve maintaining or storing the low density liquid or high density liquid or both at or above the temperature of the environment outside a reservoir.

[0569] In some embodiments, the volume of low density liquid entering or exiting an elevation region may be the about the same as the volume of high density liquid exiting or entering an elevation region. If a higher elevation reservoir operates at a different temperature than a lower elevation reservoir or if the temperature of a liquid substantially changes during transfer or a combination thereof, then 'heating' or 'cooling' or both may be required to ensure each section of the system operates within design temperature ranges. Heat recovery or thermal storage or a combination thereof may be required to ensure said 'heating' or 'cooling' or both are conducted efficiently or with minimal parasitic load related to said 'heating' or 'cooling' or both. In some embodiments, one process for heat recovery may involve heat exchanging low density liquid being transferred to a reservoir with high density liquid being transferred to an opposing reservoir. In some embodiments, during charging or discharging, the volume or volumetric flow rate or both of low density liquid being transferred to a reservoir may be the same as the volume or volumetric flow rate or both of high density liquid being transferred to an opposing reservoir. Although the volumes or volumetric flow rates or both may be the same, the heat capacity of low density liquid and high density liquid may be different. As a result, heat exchanging equal volumes of low density liquid with equal volumes of high density liquid may result in incomplete heat recovery. There are multiple embodiments which may address or benefit from or leverage or a combination thereof a difference in heat capacity between low density liquid and high density liquid. There are multiple embodiments which may enable heat recovery and / or efficient operation of different sections of a system at different temperatures.

[0570] For example, some embodiments may involve heat exchanging only a portion of the high density liquid with the low density liquid transferred in to an opposing reservoir. To enable only a portion of the high density liquid to be heat exchanged with low density liquid, high density liquid may be split into two or more streams during, for example, storing electricity or charging. One of the streams may comprise high density liquid at a flow rate such that the total heat capacity of the stream is about the same as the total heat capacity of the low density liquid, which may enable the low density liquid and high density liquid to be heat exchanged with practically full heat recovery. The other high density liquid stream may comprise the portion of high density liquid in excess of the portion with the same total heat capacity as the low density liquid. The other high density liquid stream may be heat exchanged with supplemental thermal storage. After

heat exchanging with low density liquid, or supplemental thermal storage, or both, the two high density liquid streams may be merged. If the system is undergoing storing electricity or ‘charging’, the two streams may be transferred into a higher elevation reservoir. If the system is undergoing generating electricity or ‘discharging’, the two streams may be merged into common pipes or pipe and transferred to a lower elevation reservoir. An example of the present embodiment may be shown in Figures 128 and 129. An illustrative example of the present embodiment is further described below:

- In the present example, Figure 128 is employed as a reference. ‘1’ may represent a higher elevation reservoir designed to store both low density liquid and high density liquid. ‘2’ may comprise low density liquid transferred between the higher elevation reservoir and a heat exchanger. ‘3’ may represent a heat exchanger which facilitates heat transfer between low density liquid and high density liquid. ‘4’ may represent low density liquid transferred between a heat exchanger and a pump / generator or hydraulic recovery turbine (HPRT). ‘5’ may represent a pump / generator or hydraulic power recovery turbine (HPRT). ‘6’ may represent low density liquid transferred between a pump / generator and a lower elevation reservoir. ‘7’ may represent a lower elevation reservoir designed to store both low density liquid and high density liquid. ‘8’ may represent high density liquid transferred between a lower elevation reservoir and a higher elevation region. ‘9’ may represent a liquid flow splitter (although may represent a flow merger during discharging), which splits the flow of high density liquid into two liquid streams. ‘10’ may represent a liquid stream of high density liquid with a total heat capacity about the same as the heat capacity of low density liquid and may represent high density liquid transferred between a flow splitter and a low density liquid – high density liquid heat exchanger. ‘11’ may represent a high density liquid stream after heat exchange with low density liquid and may represent high density liquid transferred between low density liquid – high density liquid heat exchanger and flow merger. ‘12’ may represent a liquid stream of high density liquid transferred between a flow splitter and a high density liquid – supplemental thermal storage heat exchanger. ‘13’ may represent a high density liquid – supplemental thermal storage heat exchanger. ‘14’ may represent a high density liquid stream after heat exchange with supplemental thermal storage. ‘15’ may represent a stream merger or flow merger (although may represent a flow splitter during discharging). ‘16’ may represent high density liquid transferred between a flow merger and a higher elevation reservoir designed to store both low density liquid and high density liquid. ‘17’ may represent a ‘warm’ supplemental thermal storage

reservoir. '18' may represent thermal storage medium or heat transfer medium transferred between a high density liquid – supplemental thermal storage heat exchanger and a 'warm' supplemental thermal storage reservoir and may represent 'warm' thermal storage medium or heat transfer medium. '19' may represent thermal storage medium or heat transfer medium transferred between a high density liquid – supplemental thermal storage heat exchanger and a 'cold' supplemental thermal storage reservoir and may represent 'cold' thermal storage medium or heat transfer medium. '20' may represent a 'cold' supplemental thermal storage reservoir. '21' may represent a cooling source or thermal management system or a combination thereof to provide cooling or thermal management to the higher elevation reservoir, or low density liquid, or high density liquid, or a combination thereof as needed. '22' may represent any heat transfer between a cooling source or thermal management system or a combination thereof and a higher elevation reservoir or low density liquid, or high density liquid, or a combination thereof.

- An example implementation of the present example may be a 50 MW (max. power), 600 MWh (max. electricity storage capacity) system with a 3,000 meter water depth lower elevation reservoir and a floating higher elevation region. The low density liquid may comprise n-Butane and the high density liquid may comprise seawater or an aqueous solution with a density about the same as seawater. Energy density of LDL displacing HDL is about 3.56 kWh per m³, which may equate to a higher elevation reservoir and a lower elevation reservoir each with a liquid storage capacity of about 167,888 m³ for a 600 MWh energy storage system. At full power capacity of 50 MW, the volumetric flow rate of LDL is about 14,045m³ / hour and the volumetric flow rate of HDL is about 14,045m³ / hour. The following are additional example specifications and calculations:
 - The higher elevation reservoir designed to store both low density liquid and high density liquid may store low density liquid and high density liquid at a temperature of -2°C. -2°C may be less than the boiling point temperature of n-Butane LDL at atmospheric pressure and may be greater than the freezing point of the aqueous solution HDL employed in this example.
 - The lower elevation reservoir designed to store both low density liquid and high density liquid is assumed to store liquid at the same temperature as deep ocean water, or about 2°C to 4°C.
 - The present example assumes the temperature of low density liquid and / or high density liquid transferred into the higher elevation region is at the same

temperature as the surface water temperature, which is a conservative assumption. The surface water temperature in the present example is assumed to be 30°C.

- The specific heat capacity of the high density liquid is 3.9 J/g°C
- The specific heat capacity of liquid normal butane is 2.275 J/g°C
- The density of high density liquid is 1030 kg per cubic meter
- The density of low density liquid is 573 kg per cubic meter
- Total volumetric flow rate of low density liquid at maximum power capacity is 14,045 m³ / hour
- Total volumetric flow rate of high density liquid at maximum power capacity is 14,045 m³ / hour
- Total mass flow rate of low density liquid at maximum power capacity is 8,048 metric tons per hour
- Total mass flow rate of high density liquid at maximum power capacity is 14,466 metric tons per hour
- Total heat capacity of low density liquid at the maximum power capacity flow rate is 18,309 MJ per °K per hour
- Total heat capacity of high density liquid at the maximum power capacity flow rate is 56,417 MJ per °K per hour
- The volumetric flow rate of the portion of high density liquid with the same total heat capacity as the low density liquid is 4,558 m³ / hour
- Percentage of total high density liquid flow comprising the portion of high density liquid with the same total heat capacity as the low density liquid is 32.45%
- The volumetric flow rate of the portion of high density liquid in excess of the portion with the same total heat capacity as the low density liquid is 9,487 m³ / hour
- Percentage of total high density liquid flow comprising the portion of high density liquid in excess of the portion with the same total heat capacity as the low density liquid is 67.55%.

[0571] Below is a table with an example simplified stream summary of the present example using Figure 128 as a reference:

ID	Composition	Flow Rate at Max. Power (m ³ /hour)	Temperature (degrees Celsius)	Volume (m ³)	Electricity (MW)
1	n-Butane and / or Water Solution	NOT APPLICABLE	-2°C	167,888 m ³	NOT APPLICABLE
2	n-Butane	14,045 m ³ / hour	-2°C	NOT APPLICABLE	NOT APPLICABLE
3	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE
4	n-Butane	14,045 m ³ / hour	30°C	NOT APPLICABLE	NOT APPLICABLE
5	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	50
6	n-Butane	14,045 m ³ / hour	30°C	NOT APPLICABLE	NOT APPLICABLE
7	n-Butane and / or Water Solution	NOT APPLICABLE	3°C	167,888 m ³	NOT APPLICABLE
8	Water Solution	14,045 m ³ / hour	30°C	NOT APPLICABLE	NOT APPLICABLE
9	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE
10	Water Solution	4,558 m ³ / hour	30°C	NOT APPLICABLE	NOT APPLICABLE
11	Water Solution	4,558 m ³ / hour	-2°C	NOT APPLICABLE	NOT APPLICABLE
12	Water Solution	9,487 m ³ / hour	30°C	NOT APPLICABLE	NOT APPLICABLE
13	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE
14	Water Solution	9,487 m ³ / hour	-2°C	NOT APPLICABLE	NOT APPLICABLE
15	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE
16	Water Solution	14,045 m ³ / hour	-2°C	NOT APPLICABLE	NOT APPLICABLE
17	Water Solution	NOT APPLICABLE	30°C	113,844 m ³ storage capacity	NOT APPLICABLE
18	Water Solution	9,487 m ³ / hour	30°C	NOT APPLICABLE	NOT APPLICABLE
19	Water Solution	9,487 m ³ / hour	-2°C	NOT APPLICABLE	NOT APPLICABLE
20	Water Solution	NOT APPLICABLE	-2°C	113,844 m ³ storage capacity	NOT APPLICABLE

[0572] Please note: Some temperatures shown in the above table may reflect the ambient temperature as a conservative estimate of temperature rather than predicting temperature changes over transfer through a pipe.

[0573] Please note: Some of the temperatures shown in the above table may not reflect the required temperature difference for heat transfer in a heat exchanger.

[0574] For example, some embodiments may involve heat exchanging only a portion of the high density liquid with the low density liquid transferred in to an opposing reservoir. To enable only a portion of the high density liquid to be heat exchanged with low density liquid, high density liquid may be split into two or more streams during, for example, storing electricity or charging. One of the streams may comprise high density liquid at a flow rate such that the total heat capacity of the stream is about the same as the total heat capacity of the low density liquid, which may enable the low density liquid and high density liquid to be heat exchanged with practically complete heat recovery. After heat exchange with low density liquid, the high density liquid stream may be transferred to a 'cold' high density liquid storage reservoir. During, for example, charging, 'cold' high density liquid may be transferred from a 'cold' high density liquid storage reservoir into a storage reservoir designed to store both high density liquid and low density liquid. The volume of high density liquid transferred into said storage reservoir designed to store both high density liquid and low density liquid may be about the same as the volume of low density liquid transferred out of said storage reservoir designed to store both high density liquid and low density liquid. The volume of high density liquid transferred into said storage reservoir designed to store both high density liquid and low density liquid may be greater than the volume of high density liquid entering the 'cold' high density liquid storage reservoir. The other high density liquid stream may comprise the portion of high density liquid in excess of the portion with the same total heat capacity as the low density liquid. The other high density liquid stream may be transferred to a 'warm' high density liquid storage reservoir. An example of the present embodiment may be shown in Figures 132 and 133. An illustrative example of the present embodiment is further described below:

- In the present example, Figure 132 is employed as a reference. '1' may represent a higher elevation reservoir designed to store both low density liquid and high density liquid. '2' may comprise low density liquid transferred between the higher elevation reservoir and a heat exchanger. '3' may represent a heat exchanger which facilitates heat transfer between low density liquid and high density liquid. '4' may represent low density liquid transferred between a heat exchanger and a pump / generator or hydraulic recovery turbine (HPRT). '5' may represent a pump / generator or hydraulic power recovery turbine (HPRT). '6' may represent low density liquid transferred between a pump / generator and a lower elevation reservoir. '7' may represent a lower elevation reservoir designed to store both

low density liquid and high density liquid. '8' may represent high density liquid transferred between a lower elevation reservoir and a higher elevation region. '9' may represent a liquid flow splitter (although may represent a flow merger during discharging), which splits the flow of high density liquid into two liquid streams. '10' may represent may represent a liquid stream of high density liquid transferred between a flow splitter and a 'warm' high density liquid storage reservoir. '11' may represent a 'warm' high density liquid storage reservoir. '12' may represent a liquid stream of high density liquid with a total heat capacity about the same as the heat capacity of low density liquid and may represent high density liquid transferred between a flow splitter and a low density liquid – high density liquid heat exchanger. '13' may represent a high density liquid stream after heat exchange with low density liquid and may represent high density liquid transferred between a low density liquid – high density liquid heat exchanger and a 'cold' high density liquid storage reservoir. '14' may represent a 'cold' high density liquid storage reservoir. '15' may comprise 'cold' high density liquid transferred between a 'cold' high density liquid storage reservoir and a higher elevation reservoir designed to store both low density liquid and high density liquid. '21' may represent a cooling source or thermal management system or a combination thereof to provide cooling or thermal management to a higher elevation reservoir, or low density liquid, or high density liquid, or a combination thereof as needed. '22' may represent any heat transfer between a cooling source or thermal management system or a combination thereof and a higher elevation reservoir or low density liquid, or high density liquid, or a combination thereof.

- An example implementation of the present example may be a 50 MW (max. power), 600 MWh (max. electricity storage capacity) system with a 3,000 meter water depth lower elevation reservoir and a floating higher elevation region. The low density liquid may comprise n-Butane and the high density liquid may comprise seawater or an aqueous solution with a density about the same as seawater. Energy density of LDL displacing HDL is about 3.56 kWh per m³, which may equate to a higher elevation reservoir and a lower elevation reservoir each with a liquid storage capacity of about 167,888 m³ for a 600 MWh energy storage system. At full power capacity of 50 MW, the volumetric flow rate of LDL is about 14,045m³ / hour and the volumetric flow rate of HDL is about 14,045m³ / hour. The following are additional example specifications and calculations:
 - The higher elevation reservoir designed to store both low density liquid and high density liquid may store low density liquid and high density liquid at a

temperature of -2°C . -2°C may be less than the boiling point temperature of n-Butane LDL at atmospheric pressure and may be greater than the freezing point of the aqueous solution HDL employed in this example.

- The lower elevation reservoir designed to store both low density liquid and high density liquid is assumed to store liquid at the same temperature as deep ocean water, or about 2°C to 4°C .
- The present example assumes the temperature of low density liquid and / or high density liquid transferred into the higher elevation region is at the same temperature as the surface water temperature, which is a conservative assumption. The surface water temperature in the present example is assumed to be 30°C .
- The specific heat capacity of the high density liquid is $3.9 \text{ J/g}^{\circ}\text{C}$
- The specific heat capacity of liquid normal butane is $2.275 \text{ J/g}^{\circ}\text{K}$
- The density of high density liquid is $1030 \text{ kg per cubic meter}$
- The density of low density liquid is $573 \text{ kg per cubic meter}$
- Total volumetric flow rate of low density liquid at maximum power capacity is $14,045 \text{ m}^3 / \text{hour}$
- Total volumetric flow rate of high density liquid at maximum power capacity is $14,045 \text{ m}^3 / \text{hour}$
- Total mass flow rate of low density liquid at maximum power capacity is $8,048 \text{ metric tons per hour}$
- Total mass flow rate of high density liquid at maximum power capacity is $14,466 \text{ metric tons per hour}$
- Total heat capacity of low density liquid at the maximum power capacity flow rate is $18,309 \text{ MJ per }^{\circ}\text{K per hour}$
- Total heat capacity of high density liquid at the maximum power capacity flow rate is $56,417 \text{ MJ per }^{\circ}\text{K per hour}$
- The volumetric flow rate of the portion of high density liquid with the same total heat capacity as the low density liquid is $4,558 \text{ m}^3 / \text{hour}$
- Percentage of total high density liquid flow comprising the portion of high density liquid with the same total heat capacity as the low density liquid is 32.45%

- The volumetric flow rate of the portion of high density liquid in excess of the portion with the same total heat capacity as the low density liquid is 9,487 m³ / hour
- Percentage of total high density liquid flow comprising the portion of high density liquid in excess of the portion with the same total heat capacity as the low density liquid is 67.55%.

- Below is a table with an example simplified stream summary of the present example using Figure 132 as a reference:

ID	Composition	Flow Rate at Max. Power (m ³ /hour)	Temperature (degrees Celsius)	Volume (m ³)	Electricity (MW)
1	n-Butane and / or Water Solution	NOT APPLICABLE	-2°C	167,888 m ³	NOT APPLICABLE
2	n-Butane	14,045 m ³ / hour	-2°C	NOT APPLICABLE	NOT APPLICABLE
3	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE
4	n-Butane	14,045 m ³ / hour	30°C	NOT APPLICABLE	NOT APPLICABLE
5	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	50
6	n-Butane	14,045 m ³ / hour	30°C	NOT APPLICABLE	NOT APPLICABLE
7	n-Butane and / or Water Solution	NOT APPLICABLE	3°C	167,888 m ³	NOT APPLICABLE
8	Water Solution	14,045 m ³ / hour	30°C	NOT APPLICABLE	NOT APPLICABLE
9	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE
10	Water Solution	9,487 m ³ / hour	30°C	NOT APPLICABLE	NOT APPLICABLE
11	Water Solution	NOT APPLICABLE	30°C	113,844 m ³ storage capacity	NOT APPLICABLE
12	Water Solution	4,558 m ³ / hour	30°C	NOT APPLICABLE	NOT APPLICABLE
13	Water Solution	4,558 m ³ / hour	-2°C	NOT APPLICABLE	NOT APPLICABLE
14	Water Solution	NOT APPLICABLE	-2°C	167,888 m ³ storage capacity	NOT APPLICABLE
15	Water Solution	14,045 m ³ / hour	-2°C	NOT APPLICABLE	NOT APPLICABLE

[0575] Please note: Some temperatures shown in the above table may reflect the ambient temperature as a conservative estimate of temperature rather than predicting temperature changes over transfer through a pipe.

[0576] Please note: Some of the temperatures shown in the above table may not reflect the required temperature difference for heat transfer in a heat exchanger.

[0577] In some embodiments, cold deep ocean water may be employed to cool low density liquid and / or high density liquid. By employing cold deep ocean water as a cooling source, the presently described embodiments may involve less capital cost or complexity. Cold deep ocean water may be harnessed using, for example, a pipe capable of transferring water between deep ocean and the higher elevation region, a water pump, and a heat exchanger. Cold deep ocean water may be heat exchanged with the portion of high density liquid in excess of the portion with the same total heat capacity as the low density liquid.

[0578] For example, some embodiments may involve heat exchanging only a portion of the high density liquid with the low density liquid transferred in to an opposing reservoir. To enable only a portion of the high density liquid to be heat exchanged with low density liquid, high density liquid may be split into two or more streams during, for example, storing electricity or charging. One of the streams may comprise high density liquid at a flow rate such that the total heat capacity of the stream is about the same as the total heat capacity of the low density liquid, which may enable the low density liquid and high density liquid to be heat exchanged with practically complete heat recovery. The other high density liquid stream may comprise the portion of high density liquid in excess of the portion with the same total heat capacity as the low density liquid. The other high density liquid stream may be heat exchanged with ‘cold’ deep ocean water. After heat exchanging with low density liquid, or ‘cold’ deep ocean water, or both, the two high density liquid streams may be merged. If the system is undergoing storing electricity or ‘charging’, the two streams may be transferred into a higher elevation reservoir designed to store both low density liquid and high density liquid. An example of the present embodiment may be shown in Figures 138 and 139. An illustrative example of the present embodiment is further described below:

- In the present example, Figure 138 is employed as a reference. ‘1’ may represent a higher elevation reservoir designed to store both low density liquid and high density liquid. ‘2’ may comprise low density liquid transferred between the higher elevation reservoir and a heat exchanger. ‘3’ may represent a heat exchanger which facilitates heat transfer between low density liquid and high density liquid. ‘4’ may represent low density liquid transferred between a heat exchanger and a pump / generator or hydraulic recovery turbine (HPRT).

‘5’ may represent a pump / generator or hydraulic power recovery turbine (HPRT). ‘6’ may represent low density liquid transferred between a pump / generator and a lower elevation reservoir. ‘7’ may represent a lower elevation reservoir designed to store both low density liquid and high density liquid. ‘8’ may represent high density liquid transferred between a lower elevation reservoir and a higher elevation region. ‘9’ may represent a liquid flow splitter (although may represent a flow merger during discharging), which splits the flow of high density liquid into two liquid streams. ‘10’ may represent a liquid stream of high density liquid with a total heat capacity about the same as the heat capacity of low density liquid and may represent high density liquid transferred between a flow splitter and a low density liquid – high density liquid heat exchanger. ‘11’ may represent a high density liquid transferred between a low density liquid – high density liquid heat exchanger and a flow merger (although may represent a flow merger during discharging). ‘12’ may represent a liquid stream of high density liquid transferred between a flow splitter and a cooling heat exchanger. ‘13’ may represent a cooling heat exchanger which may heat exchange cold deep ocean water with the high density liquid. ‘14’ may represent high density liquid transferred between a cooling heat exchanger and a flow merger. ‘15’ may represent a flow merger (although may represent a flow merger during discharging). ‘16’ may represent ‘cold’ high density liquid transferred between a flow merger and a higher elevation reservoir designed to store both low density liquid and high density liquid. ‘17’ may represent ‘warm’ cooling liquid or ‘warm’ deep ocean water being returned to the ocean after heat exchanging. ‘18’ may represent ‘cold’ cooling liquid or ‘cold’ deep ocean water being transferred to a heat exchanger as a cooling medium. ‘21’ may represent a cooling source or thermal management system or a combination thereof to provide additional cooling or thermal management to a higher elevation reservoir, or low density liquid, or high density liquid, or a combination thereof if needed. ‘22’ may represent heat transfer between a cooling source or thermal management system or a combination thereof and a higher elevation reservoir or low density liquid, or high density liquid, or a combination thereof.

- An example implementation of the present example may be a 50 MW (max. power), 600 MWh (max. electricity storage capacity) system with a 3,000 meter water depth lower elevation reservoir and a floating higher elevation region. The low density liquid may comprise n-Butane and the high density liquid may comprise seawater or an aqueous solution with a density about the same as seawater. Energy density of LDL displacing

HDL is about 3.56 kWh per m³, which may equate to a higher elevation reservoir and a lower elevation reservoir each with a liquid storage capacity of about 167,888 m³ for a 600 MWh energy storage system. At full power capacity of 50 MW, the volumetric flow rate of LDL is about 14,045 m³ / hour and the volumetric flow rate of HDL is about 14,045 m³ / hour. The following are additional example specifications and calculations:

- The higher elevation reservoir designed to store both low density liquid and high density liquid may store low density liquid and high density liquid at a temperature of 5°C.
- The lower elevation reservoir designed to store both low density liquid and high density liquid is assumed to store liquid at the same temperature as deep ocean water, or about 2°C to 4°C.
- The present example assumes the temperature of low density liquid and / or high density liquid transferred into the higher elevation region is at the same temperature as the surface water temperature, which is a conservative assumption. The surface water temperature in the present example is assumed to be 30°C.
- The specific heat capacity of the high density liquid is 3.9 J/g°C
- The specific heat capacity of liquid normal butane is 2.275 J/g°C
- The specific heat capacity of ocean water is 4 J/g°C
- The density of high density liquid is 1030 kg per cubic meter
- The density of low density liquid is 573 kg per cubic meter
- The density of ocean water is 1030 kg per cubic meter
- Total volumetric flow rate of low density liquid at maximum power capacity is 14,045 m³ / hour
- Total volumetric flow rate of high density liquid at maximum power capacity is 14,045 m³ / hour
- Total mass flow rate of low density liquid at maximum power capacity is 8,048 metric tons per hour
- Total mass flow rate of high density liquid at maximum power capacity is 14,466 metric tons per hour
- Total heat capacity of low density liquid at the maximum power capacity flow rate is 18,309 MJ per °K per hour

- Total heat capacity of high density liquid at the maximum power capacity flow rate is 56,417 MJ per °K per hour
- The volumetric flow rate of the portion of high density liquid with the same total heat capacity as the low density liquid is 4,558 m³ / hour
- Percentage of total high density liquid flow comprising the portion of high density liquid with the same total heat capacity as the low density liquid is 32.45%
- The volumetric flow rate of the portion of high density liquid in excess of the portion with the same total heat capacity as the low density liquid is 9,487 m³ / hour
- Percentage of total high density liquid flow comprising the portion of high density liquid in excess of the portion with the same total heat capacity as the low density liquid is 67.55%.
- Total volumetric flow rate of deep ocean cooling water at max power capacity during charging is 9,250 m³ / hour
- Below is a table with an example simplified stream summary of the present example using Figure 138 as a reference:

ID	Composition	Flow Rate at Max. Power (m ³ /hour)	Temperature (degrees Celsius)	Volume (m ³)	Electricity (MW)
1	n-Butane and / or Water Solution	NOT APPLICABLE	5°C	167,888 m ³	NOT APPLICABLE
2	n-Butane	14,045 m ³ / hour	5°C	NOT APPLICABLE	NOT APPLICABLE
3	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE
4	n-Butane	14,045 m ³ / hour	30°C	NOT APPLICABLE	NOT APPLICABLE
5	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	50
6	n-Butane	14,045 m ³ / hour	30°C	NOT APPLICABLE	NOT APPLICABLE
7	n-Butane and / or Water Solution	NOT APPLICABLE	3°C	167,888 m ³	NOT APPLICABLE
8	Water Solution	14,045 m ³ / hour	30°C	NOT APPLICABLE	NOT APPLICABLE
9	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE
10	Water Solution	4,558 m ³ / hour	30°C	NOT APPLICABLE	NOT APPLICABLE
11	Water Solution	4,558 m ³ / hour	5°C	NOT APPLICABLE	NOT APPLICABLE

12	Water Solution	9,487 m ³ / hour	30°C	NOT APPLICABLE	NOT APPLICABLE
13	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE
14	Water Solution	9,487 m ³ / hour	5°C	NOT APPLICABLE	NOT APPLICABLE
15	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE
16	Water Solution	14,045 m ³ / hour	5°C	NOT APPLICABLE	NOT APPLICABLE
17	Cold Deep Ocean Water Supply	9,250 m ³ / hour	5°C	NOT APPLICABLE	NOT APPLICABLE
18	Warm Deep Ocean Water Return	9,250 m ³ / hour	5°C	NOT APPLICABLE	NOT APPLICABLE

[0579] Please note: Some temperatures shown in the above table may reflect the ambient temperature as a conservative estimate of temperature rather than predicting temperature changes over transfer through a pipe.

[0580] Please note: Some of the temperatures shown in the above table may not reflect the required temperature difference for heat transfer in a heat exchanger.

[0581] In some embodiments, a semi-pressurized tank may be employed. In some embodiments employing cold deep ocean water for cooling, a semi-pressurized tank may be employed due to the low density liquid possessing an atmospheric pressure boiling point temperature less than the temperature of the cold deep ocean water. For example, n-Butane may have a boiling point between -1°C and 1°C at atmospheric pressure and cold deep ocean water may be about 5°C after transfer to the ocean surface. At 5°C, n-Butane has a vapor pressure of about 1.2 atmospheres of pressure. A semi-pressurized tank may possess a design pressure greater than or equal to 1.2 atmospheres of pressure.

[0582] In some embodiments, ‘heated’ or ‘heating’ may involve increasing the temperature of a liquid at one elevation and, once at a desired temperature, transferring said liquid to a different elevation. Similarly, in some embodiments, ‘cooled’ or ‘cooling’ may involve decreasing the temperature of a liquid at one elevation and, once at a desired temperature, transferring said liquid to a different elevation. For example, low density liquid transferred from a higher elevation reservoir to a lower elevation reservoir may be heated in a higher elevation region before or while being transferred to the lower elevation reservoir. For example, high density liquid transferred from a higher elevation reservoir to a lower elevation reservoir may be heated in a higher elevation region before or while being transferred to the lower elevation reservoir. For example, low density

liquid transferred from a lower elevation reservoir to a higher elevation reservoir may be cooled in a lower elevation region before or while being transferred to the higher elevation reservoir. For example, high density liquid transferred from a lower elevation reservoir to a higher elevation reservoir may be cooled in a lower elevation region before or while being transferred to the higher elevation reservoir.

[0583] In some embodiments, ‘heated’ or ‘heating’ may involve increasing the temperature of a liquid at an elevation and transferring said liquid into a reservoir of similar or the same elevation or in the same elevation region. Similarly, in some embodiments, ‘cooled’ or ‘cooling’ may involve decreasing the temperature of a liquid at an elevation and transferring said liquid into a reservoir of similar or the same elevation or in the same elevation region. In some embodiments, cooling or heating or both may be conducted within a reservoir or may be applied to a reservoir directly.

[0584] In some embodiments, heating or cooling or both may be conducted at different elevations, or at about the same elevation, or within or applied directly to a reservoir, or a combination thereof.

[0585] The ‘state of charge’ may comprise the amount of energy stored in an energy storage system relative to the total practical or design energy storage capacity of the energy storage system. In some embodiments, the state of charge may be defined by the percentage of low density liquid in the higher elevation reservoir.

[0586] Notes

- In some embodiments, the higher density liquid may possess a freezing point lower than the boiling point of the lower density liquid at the pressure in a higher elevation reservoir. In some embodiments, the high density liquid may comprise a liquid with a similar density or practically the same density as seawater or ocean water. Seawater or solutions with similar salt concentration to seawater may possess a sufficiently low freezing point for some low density liquids, for example, n-butane possesses a boiling point temperature at atmospheric pressure greater than the freezing point of seawater. In some embodiments, the high density liquid may possess a freezing point lower than the freezing point of seawater. For example, a lower freezing point than seawater may be achieved by adding antifreeze additives to water or an aqueous solution to create a solution with a similar density to seawater and a lower freezing point than seawater. Antifreeze additives may include, but are not limited to, one or more or a combination of the following: water soluble organic compounds, salts, glycols, ethylene glycol, propylene glycol, methanol, ethanol,

glycerol, polyols, or isopropanol. For example, a lower freezing point than seawater may be achieved by combining antifreeze additives with lower and / or higher density than seawater with water to create a solution with a similar density to seawater and a lower freezing point than seawater. Antifreeze additives may include, but are not limited to, one or more or a combination of the following: water soluble organic compounds, salts, glycols, ethylene glycol, propylene glycol, methanol, ethanol, glycerol, polyols, or isopropanol.

- Systems may be employed to minimize or prevent hydraulic ram, which can occur in incompressible liquid systems during changes in liquid flow rate. Systems and methods for compensating for or minimizing hydraulic ram include, but are not limited to, one or more or a combination of the following: overpressure tanks, or over fill tanks, or pressurized gas compensation, or water towers, or liquid towers, or gravity towers, or expansion tanks, or systems and methods known in the art.
- In some embodiments, it may be desirable for high density liquid to contain additives which reduce the viscosity of the high density liquid. For example, ethanol, methanol, or propanol may be added in addition to additives with greater density than water to create a solution with a lower viscosity than a solution with only additives with greater density than water, or a lower viscosity than seawater, or a combination thereof.
- Some embodiments may employ a subsea pump or subsea generator or both or a combination thereof. A subsea pump or subsea generator or both or a combination thereof may be desirable, for example, in some embodiments employing subsea cables.
- Some embodiments may employ the high density liquid as a thermal storage medium.
- Some embodiments may employ a heat exchanger which directly contacts high density liquid with low density liquid in a heat exchange. Directly contacting high density liquid with low density liquid in a heat exchange may result in, including, but not limited to, one or more or a combination of the following: reduce the required heat exchanger temperature difference during heat exchange, or increase energy efficiency, or reduce the capital cost of a heat exchanger, or reduce the required size of a heat exchanger, or reduce the pressure losses, or improve round trip energy efficiency, or reduce parasitic load.
- In some embodiments, high density liquid may be in direct contact with low density liquid at various points in the system. For example, in some embodiments, high density liquid is in direct contact with low density liquid in a lower elevation reservoir, or in a higher elevation reservoir, or a combination thereof. For example, in some embodiments, a

thermal storage medium may comprise the same composition as or may comprise the high density liquid. For example, in some embodiments, heat exchange between the low density liquid and high density liquid may involve directly contacting high density liquid and low density liquid. For example, in some embodiments, heat exchange between the low density liquid and high density liquid may involve directly mixing and demixing high density liquid and low density liquid. For example, in some embodiments, heat exchange between the low density liquid and thermal storage medium may involve directly contacting thermal storage medium and low density liquid.

- Some embodiments may employ more than one low density liquid pipe or riser and / or more than one high density liquid pipe or riser. Employing more than one pipe or riser may be desirable in some embodiments due to, for example, including, but not limited to, one or more or a combination of the following: reduce installation cost, match installation capabilities, limits of installation capabilities, reducing CAPEX, increasing redundancy, longevity, connecting with more than one lower elevation tank, connecting with more than one higher elevation tank, connecting to more than one pump or generator or a combination thereof.
- In some embodiments, low density liquid and high density liquid may be stored in the lower elevation reservoir and the higher elevation reservoir within at least a portion of the same tanks. For example, during storing electricity or ‘charging’, LDL may displace HDL in the lower elevation reservoir and HDL may displace LDL in the higher elevation reservoir. For example, during generating electricity or ‘discharging’, HDL may displace LDL in the lower elevation reservoir and HDL may displace LDL in the higher elevation reservoir.
- In some embodiments, the LDL in the higher elevation reservoir may comprise a low boiling point low density liquid and may require cooling or to be stored at a temperature below some ambient temperature in the higher elevation reservoir. In some embodiments, such as embodiments with low density liquid and high density liquid stored in the lower elevation reservoir and the higher elevation reservoir within at least a portion of the same tanks, it may be desirable for the HDL to function as a form of thermal storage or a thermal storage medium. For example, during generating electricity or ‘discharging’, ‘cold’ HDL exiting a higher elevation reservoir may be heat exchanged with ‘warm’ LDL entering a higher elevation reservoir, resulting in ‘cold’ LDL entering a higher elevation reservoir and ‘warm’ HDL transferred to a lower elevation reservoir.

- In some embodiments, it is important to note the volume of LDL and HDL entering or exiting higher elevation regions and lower elevation regions during storing electricity (charging) or generating electricity (discharging) may be the same or similar, however, the density and specific heat capacity of the HDL and LDL may be different. For example, HDL may possess a greater density and / or greater specific heat capacity than LDL. HDL may possess greater total heat capacity than LDL for the same volume of liquid. Heat exchanging equal volumes of HDL and LDL may result in greater temperature change of LDL than HDL and may result in incomplete heat recovery. There are multiple configurations which may be employed to more efficiently recover heat from entering and exiting HDL or exiting and entering LDL. Said configurations may include, but are not limited to, one or more or a combination of the following summarized below:
 - In some embodiments, only a portion of HDL is heat exchanged with LDL during the transfer of LDL and HDL between the higher elevation and lower elevation reservoirs. Said portion may comprise an amount of HDL with a total heat capacity similar or the same as the total heat capacity of the LDL heat exchanged with said portion of HDL.
 - In some embodiments, only a portion of HDL is heat exchanged with LDL during the transfer of LDL and HDL between the higher elevation and lower elevation reservoirs. The other portion of HDL may be heat exchanged with a supplemental thermal storage. Said 'portion' of HDL and 'other portion' of HDL may be merged into the same pipe or pipes before or during transferring from the higher elevation portion to the lower elevation portion.
 - In some embodiments, only a portion of HDL is heat exchanged with LDL during the transfer of LDL and HDL between the higher elevation and lower elevation reservoirs.
 - During storing electricity or 'charging', said portion of HDL may be stored in a 'cold' HDL storage tank after heat exchanging. Said 'cold' HDL storage tank may transfer a volume of 'cold' HDL into a tank designed to store both HDL and LDL. Said volume of 'cold' HDL transferred into a tank designed to store both HDL and LDL may comprise a volume of HDL about the same as the volume of LDL exiting said tank designed to store both HDL and LDL. Said volume of 'cold' HDL transferred into a tank designed to store both HDL and LDL

may comprise a volume of HDL greater than the volume of HDL in said 'portion' of HDL. The other portion of HDL, which may comprise HDL not heat exchanged with LDL during the transfer of LDL and HDL between the higher elevation and lower elevation reservoirs, may be stored in a 'warm' HDL storage tank.

- During generating electricity or 'discharging', a volume of 'cold' HDL may be transferred from said tank designed to store both HDL and LDL into said 'cold' HDL storage tank and / or an equivalent volume of LDL may enter said tank designed to store both HDL and LDL. A portion of HDL is transferred from said 'cold' HDL storage tank and heat exchanged with LDL before or during the transfer of said LDL into said tank designed to store both HDL and LDL. Additionally, HDL representing 'other portion of HDL' may be transferred from said 'warm' HDL storage tank. Said 'portion' of HDL and 'other portion' or HDL may be merged into the same pipe or pipes before or during transferring from the higher elevation portion to the lower elevation portion.
- Electricity may be provided as an example of work stored or generated or transferred or a combination thereof. If desired, other forms of work may be stored or generated or transferred, which may include, but are not limited to, one or more or a combination of the following: hydraulic work, or pneumatic work, or mechanical work.
- If the density of high density liquid is practically the same as the density of water surrounding a lower elevation reservoir, the pressure inside a lower elevation reservoir may be close to or practically the same as the pressure outside or surrounding or adjacent to said lower elevation reservoir.
- In some embodiments, HDL may comprise a thermal storage medium.
- Some embodiments may employ direct contact heat exchangers. For example, if low density liquid is insoluble in or fully saturated in high density liquid, low density liquid and high density liquid may be directly contacted during a heat exchange. Direct contact heat exchange may have multiple advantages, which may include, but are not limited to, one or more or a combination of the following: lower heat exchange delta T, or lower CAPEX, or greater energy efficiency, or less corrosion, or less surfaces, or less fouling, or lower pressure drop.

- A possible direct contactor heat exchanger may involve a column comprising a high density liquid input, a high density liquid output, a low density liquid input, and a low density liquid output. Low density liquid input may be located near the bottom of the column. The high density liquid input may be located near the top of the column. The low density liquid output may be located near the top of the column. The high density liquid output may be located near the bottom of the column. For example, low density liquid may enter near the bottom of the column and float to the top of the column. For example, high density liquid may enter near the top of the column and sink to the bottom of the column. During the floating of low density liquid and the sinking of high density liquid, the low density liquid and high density liquid may heat exchange and heat transfer may occur. If desired, the column may contain packing material. If desired, the column may contain agitation. If desired, one column or more than one column may be employed.
- In some embodiments, it may be desirable to store low density liquid and high density liquid at relatively high temperature within environments with total pressures near or greater than or equal to the pressures required for hydrate formation. In some embodiments, said relatively high temperature may comprise a temperature greater than hydrate formation temperatures. In some embodiments, said environments with total pressures near or greater than or equal to the pressures required for hydrate formation may comprise a lower elevation reservoir, or a pipe, or a combination thereof. In some embodiments, it may be desirable to heat the low density liquid, or high density liquid, or both to said relatively high temperature before, or during, or after, transferring said low density liquid, or high density liquid from a higher elevation reservoir to a lower elevation reservoir. It may be desirable to employ heated low density liquid and / or high density liquid in total pressures near or greater than or equal to the pressures required for hydrate formation to prevent hydrate formation, or enable safe liquid handling, or enable direct liquid-liquid contact, or a combination thereof. It may be desirable tanks, pipes, and / or other equipment to comprise at least a portion of insulation to, for example, minimize heat or 'cool' losses and / or reduce heating and / or cooling parasitic load. In some embodiments, it may be desirable to countercurrent heat exchange or otherwise heat exchange low density liquid and high density liquid during transfer to enable recovery of heat and 'cool' and minimize heating and / or cooling parasitic energy demands. In some embodiments, it may be desirable to employ high temperature and / or low temperature supplemental thermal storage.

Example Figure Descriptions

[0587] Figure 140A: The present embodiment shown in the present figure may show an energy storage system which stores energy by displacing a high density fluid with a low density fluid. The present figure may show an embodiment employing a power exchanger (which may also be referred to as a pressure exchanger, or energy recovery device or unit, or power recovery device or unit). In the present embodiment, a power exchanger may be located in a lower elevation region near a lower elevation reservoir. A power exchanger may recover a portion of hydraulic power from a low density liquid stream and transfer the portion of recovered hydraulic power to a high density liquid stream. For example, a power exchanger may comprise a turbine or pump or pressure exchanger ('5') on a low density liquid stream, a mechanical or hydraulic or pneumatic or electrical power transmission method ('10'), and / or a turbine or pump or pressure exchanger ('5') on a high density liquid stream. For example, in the present figure, a power exchanger may transfer sufficient power or pressure from a low density liquid stream to a high density liquid stream to apply sufficient pressure to the high density liquid stream to enable the high density liquid stream to overcome the pressure difference or pressure drop or pressure losses in the transfer of high density liquid from a lower elevation reservoir to a higher elevation reservoir ('12'). For example, in the present figure, the power exchanger may provide pressure or power transfer between the low density liquid and high density liquid, while enabling the lower elevation reservoir ('7') to remain at a relatively stable or constant pressure or with minimal change in the pressure of the lower elevation reservoir. The present figure may show power may be recovered and transferred from a low density liquid to a high density liquid stream, or power may be recovered and transferred from a high density liquid to a low density liquid stream, or a combination thereof. The present figure may show an embodiment with a pressure equalizer and / or pressure sensor ('8') connected to a lower elevation reservoir ('7'). The present figure may show a thermally managed or cooled or refrigerated or a combination thereof ('14' and '15') low density liquid higher elevation reservoir ('1'). The present figure may show the present embodiment storing electricity or 'charging'.

[0588] Figure 140B: The present figure may be the same as Figure 140A, although may show a portion of hydraulic power may be transferred from a low density liquid stream to a high density liquid stream when storing electricity or 'charging'.

[0589] Figure 140C: The present figure may be the same as Figure 140A, although may show a low density liquid higher elevation reservoir without thermal management, or cooling, or refrigeration.

[0590] Figure 141A: The present figure may be the same as Figure 140A, although may show the present embodiment generating electricity or ‘discharging’. In some embodiments, during discharging, high density liquid may bypass a power exchanger (‘11’) and / or low density liquid may bypass a power exchanger (‘5’) when the system is generating electricity or ‘discharging’. In some embodiments, a supplemental pump may add supplemental pressure to the high density liquid transferred from a higher elevation reservoir to a lower elevation reservoir to, for example, overcome or compensate for pressure losses or pressure drop during transfer from the higher elevation reservoir to the lower elevation reservoir, and / or to ensure the pressure of high density liquid inside the lower elevation reservoir is about the same as the pressure surrounding or adjacent to or outside the lower elevation reservoir, and / or a combination thereof. Said supplemental pump, which may not be shown in the present figure, may be located in the higher elevation region, or the lower elevation region, or at another point in the process, or a combination thereof.

[0591] Figure 141B: The present figure may be the same as Figure 140B, although may show the present embodiment generating electricity or ‘discharging’. The present figure may show a portion of hydraulic power may be transferred from a high density liquid stream to a low density liquid stream when generating electricity or ‘discharging’.

[0592] Figure 141C: The present figure may be the same as Figure 140A, although may show a low density liquid higher elevation reservoir without thermal management, or cooling, or refrigeration.

[0593] Figure 142A: The present embodiment shown in the present figure may show an energy storage system which stores energy by displacing a high density fluid with a low density fluid. The present figure may show an embodiment employing a power exchanger. In the present embodiment, the power exchanger may comprise a power recovery or pressure exchanger device which may be housed in one unit. The power exchanger may comprise hydraulic, and / or mechanical power or pressure transfer. The power exchanger may comprise electrical power or pressure transfer. The power exchanger may comprise pneumatic power or pressure transfer. The present figure may show a power exchanger (‘9’) recovering excess pressure or power from a low density liquid stream (‘4’) before the low density liquid stream enters a lower elevation reservoir (‘6’) and transferring said excess pressure or power to a high density liquid stream (‘9’), which may result in a high density liquid stream (‘10’) with sufficient pressure to overcome or compensate for pressure drop or pressure losses during the transfer of high density liquid from a lower elevation reservoir to a higher elevation reservoir. The present figure may show an embodiment with a pressure equalizer and / or pressure sensor (‘8’) connected to a lower elevation

reservoir ('7'). The present figure may show a thermally managed or cooled or refrigerated or a combination thereof ('14' and '15') low density liquid higher elevation reservoir ('1'). The present figure may show the present embodiment storing electricity or 'charging'.

[0594] Figure 142B: The present embodiment shown in the present figure may be the same as Figure 142A, although may show a low density liquid higher elevation reservoir without thermal management, or cooling, or refrigeration.

[0595] Figure 143A: The present figure may be the same as Figure 142A, although may show the present embodiment generating electricity or 'discharging'. In some embodiments, during discharging, high density liquid may bypass a power exchanger ('9') and / or low density liquid may bypass a power exchanger ('9') when the system is generating electricity or 'discharging'. In some embodiments, a supplemental pump may add supplemental pressure to the high density liquid transferred from a higher elevation reservoir to a lower elevation reservoir to, for example, overcome or compensate for pressure losses or pressure drop during transfer from the higher elevation reservoir to the lower elevation reservoir, and / or to ensure the pressure of high density liquid inside the lower elevation reservoir is about the same as the pressure surrounding or adjacent to or outside the lower elevation reservoir, and / or a combination thereof. Said supplemental pump, which may not be shown in the present figure, may be located in the higher elevation region, or the lower elevation region, or at another point in the process, or a combination thereof.

[0596] Figure 143B: The present embodiment shown in the present figure may be the same as Figure 143A, although may show a low density liquid higher elevation reservoir without thermal management, or cooling, or refrigeration.

[0597] Figure 144: The present embodiment shown in the present figure may show an energy storage system which stores energy by displacing a high density fluid with a low density fluid. The present figure may show an embodiment employing a mechanism ('11') to remove or separate a portion of low density liquid present in the high density liquid before or while storing high density liquid in a higher elevation reservoir. Removed or separated low density liquid may be transferred to one or more sections of the process designed to store low density liquid.

[0598] Figure 145: The present embodiment shown in the present figure may show an energy storage system which stores energy by displacing a high density fluid with a low density fluid. The present figure may show an embodiment with a higher elevation reservoir designed to store both low density liquid and high density liquid and / or may be thermally managed, such as cooled or refrigerated. The present figure may show an embodiment with a counter current heat exchange

between low density liquid and high density liquid. The present figure may show the present embodiment storing electricity or ‘charging’.

[0599] Figure 146: The present figure may be the same as Figure 145, although may show the present embodiment generating electricity or ‘discharging’.

[0600] Figure 147: The present figure may be the same as Figure 145, although may show additional supplemental cooling of the high density liquid during ‘charging’ after heat exchange with the low density liquid. Additional supplemental cooling of the high density liquid may be required in some embodiments due to, for example, the greater heat capacity of the high density liquid for the same liquid volume as low density liquid.

[0601] Figure 148: The present embodiment shown in the present figure may show an energy storage system which stores energy by displacing a high density fluid with a low density fluid. The present figure may show an embodiment with a higher elevation low density liquid reservoir located in a separate location than a higher elevation high density liquid reservoir. For example, the present figure may show the higher elevation high density liquid reservoir located on a floating structure and the higher elevation low density liquid reservoir located onshore. The present figure may show the present embodiment at a discharged state.

[0602] Figure 149: The present figure may be the same as Figure 148, although may show the present embodiment storing power or ‘charging’.

[0603] Figure 150: The present figure may be the same as Figure 148, although may show the present embodiment at a charged state.

[0604] Figure 151: The present figure may be the same as Figure 148, although may show the present embodiment generating power or ‘discharging’.

[0605] Figure 152: The present figure may show a rigid tank with a pressure equalizer. The present figure may comprise a lower elevation reservoir while a process is storing electricity or ‘charging’. The present figure may comprise a higher elevation reservoir while a process is generating electricity or ‘discharging’. The pressure equalizer may include, but is not limited to, a flow meter, a flow controller, a bladder tank (‘6’), a valve, a connect/disconnect device, a pressure sensor, or a combination thereof. The pressure equalizer may mitigate pressure changes or pressure waves or overpressure events. The pressure equalizer may monitor the pressure inside the rigid tank relative to the pressure outside, or surrounding, or adjacent to the rigid tank. The pressure equalizer may ensure the pressure inside the rigid tank is similar to or equal to the pressure outside, or surrounding, or adjacent to the rigid tank. The pressure equalizer may be isolatable from the rigid tank, or detachable from the rigid tank. It is important to note the bladder tank of

the pressure equalizer may be a substantially smaller volume than the volumetric capacity of the rigid tank. It is important to note the volume of liquid in the bladder tank of the pressure equalizer may remain relatively constant during normal operation, including, for example, when the energy storage process is charging, or discharging, or at a steady state. The pressure equalizer may be employed to monitor the pressure inside a reservoir relative to the pressure outside a reservoir, communicate pressure information to flow control equipment (such as pumps, turbines, and valves), and mitigate the impacts of potential underpressure or overpressure events. The bladder tank may be substituted or supplemented with a piston or similar pressure equalizing tank. In some embodiments, a pressure equalizer may comprise an expansion tank.

[0606] Figure 153: The present figure may show a rigid tank with a pressure equalizer. The present figure may comprise a higher elevation reservoir while a process is storing electricity or ‘charging’. The present figure may comprise a lower elevation reservoir while a process is generating electricity or ‘discharging’.

[0607] Figure 154: The present embodiment shown in the present figure may show an energy storage system which stores energy by displacing a high density fluid with a low density fluid. The present figure may show an embodiment with a higher elevation reservoir configured to store both low density liquid and high density liquid and a power exchanger near or in a lower elevation region. The present figure may show an embodiment with thermal management and / or heat exchange between low density liquid and high density liquid. The present figure may show the present embodiment storing electricity or ‘charging’.

[0608] Figure 155: The present figure may be the same as Figure 154, although the present figure may show the present embodiment generating electricity or ‘discharging’.

[0609] Figure 156: The present embodiment shown in the present figure may show an energy storage system which stores energy by displacing a high density fluid with a low density fluid. The present figure may show an embodiment with a higher elevation reservoir configured to store both low density liquid and high density liquid and a power exchanger near or in a lower elevation region. The present figure may show an embodiment with thermal management of the low density liquid and / or high density liquid in a higher elevation reservoir. The present figure may show the present embodiment storing electricity or ‘charging’.

[0610] Figure 157: The present figure may be the same as Figure 156, although the present figure may show the present embodiment generating electricity or ‘discharging’.

[0611] Figure 158: The present embodiment shown in the present figure may show an energy storage system which stores energy by displacing a high density fluid with a low density fluid.

The present figure may show an embodiment with a pump fluidly connected to high density liquid in a lower elevation region. Said pump may be employed to add supplemental pressure to the high density liquid, wherein said supplemental pressure is equal to or greater than the pressure difference or pressure drop or pressure loss required to transfer high density liquid from a lower elevation region to a higher elevation region at a desired flow rate. Said pump may be powered by electricity. Said pump may be powered by electricity supplied by a subsea cable. Said pump may be powered by electricity supplied by a power exchanger. Said pump may be powered electrically, or hydraulically, or mechanically, or pneumatically, or a combination thereof. The present figure may show the present embodiment storing electricity or ‘charging’.

[0612] Figure 159: The present embodiment shown in the present figure may show an energy storage system which stores energy by displacing a high density fluid with a low density fluid. The present figure may show an embodiment with a pump fluidly connected to high density liquid in a higher elevation region. Said pump may be employed to add supplemental pressure to the high density liquid, wherein said supplemental pressure is equal to or greater than the pressure difference or pressure drop or pressure loss required to transfer high density liquid from a higher elevation region to a lower elevation region at a desired flow rate. Said pump may be employed to add supplemental pressure to the high density liquid to ensure, for example, the pressure of the high density liquid in the lower elevation reservoir during discharging or generating electricity is about equal to or similar to the hydrostatic pressure outside of or adjacent to said lower elevation reservoir. Said pump may be powered by electricity. Said pump may be powered electrically, or hydraulically, or mechanically, or pneumatically, or a combination thereof. The present figure may show the present embodiment generating electricity or ‘discharging’.

Example Figure Keys

[0613] Figures 140A-C, 141A-C:

Label	Description
1	Higher elevation low density liquid reservoir. May comprise one or more storage tanks or storage devices. May be atmospheric pressure, or semi-pressurized, or pressurized, or a combination thereof. May be semi-refrigerated or fully refrigerated, or non-refrigerated, or a combination thereof.
2	Pipe transferring low density liquid between a higher elevation low density liquid reservoir and a pump.
3	Pump and / or turbine or Hydraulic Power Recovery Turbine (HPRT)
4	Pipe transferring low density liquid between a pump and a power exchanger, or between higher elevation parts and lower elevation parts, or a combination thereof.
5	A power exchanger. A power exchanger may be located in a lower elevation region near a lower elevation reservoir. A power exchanger may be located between a higher elevation region and a lower elevation region. ‘5’ may comprise

	a turbine and / or pump which may recover excess pressure in the low density liquid being transferred to a lower elevation reservoir. If desired, 'excess pressure' may be equal to or greater than the power required and / or pressure loss to transfer high density liquid from a lower elevation reservoir to a higher elevation reservoir.
6	Pipe transferring low density liquid between a power exchanger and a lower elevation reservoir.
7	A lower elevation reservoir which may be configured to store both low density liquid and high density liquid.
8	A pressure equalizer, or pressure sensor, or a combination thereof.
9	A pipe transferring high density liquid between a lower elevation reservoir and a power exchanger.
10	Represents the exchange of power between power exchangers or turbines or pumps or a combination thereof. '10' may comprise a transfer of power, which may comprise, including, but not limited to, hydraulic, or electrical, or mechanical, or pneumatic, or a combination thereof power transfer.
11	A power exchanger. A power exchanger may be located in a lower elevation region near a lower elevation reservoir. A power exchanger may be located between a higher elevation region and a lower elevation region. '11' may comprise a pump and / or turbine which may apply pressure to the high density liquid to facilitate the transfer of high density liquid from a lower elevation reservoir to a higher elevation reservoir. If desired, said application of pressure may be powered by excess power or pressure recovered from a low density liquid stream. Said application of pressure may be equal to or greater than the pressure drop or pressure loss of high density liquid transferred from a lower elevation reservoir to a higher elevation reservoir at a desired volumetric flow rate.
12	A pipe transferring high density liquid between a power exchanger and a higher elevation reservoir.
13	A higher elevation high density liquid reservoir. May comprise one or more storage tanks or storage devices.
14	May represent the transfer of heat, or fluids, or working fluids, or a combination thereof to facilitate cooling, or heating, or thermal management, or a combination thereof of the low density liquid, or high density liquid, or both.
15	A process for cooling, or heating, or thermal management, or a combination thereof. '15' may employ ocean water or deep-sea ocean water as a heat sink.
Higher Elevation	Label for an adjacent dashed box. Said adjacent dashed box may comprise higher elevation parts.
Lower Elevation	Label for an adjacent dashed box. Said adjacent dashed box may comprise lower elevation parts.

[0614] Figures 142A-B, 143A-B:

Label	Description
1	Higher elevation low density liquid reservoir. May comprise one or more storage tanks or storage devices. May be atmospheric pressure, or semi-pressurized, or pressurized, or a combination thereof. May be semi-refrigerated or fully refrigerated, or non-refrigerated, or a combination thereof.
2	Pipe transferring low density liquid between a higher elevation low density liquid reservoir and a pump.

3	Pump and / or turbine or Hydraulic Power Recovery Turbine (HPRT)
4	Pipe transferring low density liquid between a pump and a power exchanger, or between higher elevation parts and lower elevation parts, or a combination thereof.
5	Pipe transferring low density liquid between a power exchanger and a lower elevation reservoir.
6	A lower elevation reservoir which may be configured to store both low density liquid and high density liquid.
7	A pressure equalizer, or pressure sensor, or a combination thereof.
8	A pipe transferring high density liquid between a lower elevation reservoir and a power exchanger.
9	A power exchanger. A power exchanger may be located in a lower elevation region near a lower elevation reservoir. A power exchanger may be located between a higher elevation region and a lower elevation region. '9' may comprise a turbine and / or pump which may recover excess pressure in the low density liquid being transferred to a lower elevation reservoir. If desired, 'excess pressure' may be equal to or greater than the power required and / or pressure loss to transfer high density liquid from a lower elevation reservoir to a higher elevation reservoir. '9' may transfer power between a low density liquid stream and a high density liquid stream, which may comprise, including, but not limited to, hydraulic, or electrical, or mechanical, or pneumatic, or a combination thereof power transfer. '9' may be designed to transfer pressure or power or both from low density liquid to high density liquid, or from high density liquid to low density liquid, or to a combination thereof.
10	A pipe transferring high density liquid between a power exchanger and a higher elevation reservoir.
11	A higher elevation high density liquid reservoir. May comprise one or more storage tanks or storage devices.
Higher Elevation	Label for an adjacent dashed box. Said adjacent dashed box may comprise higher elevation parts.
Lower Elevation	Label for an adjacent dashed box. Said adjacent dashed box may comprise lower elevation parts.

[0615] Figure 144:

Label	Description
1	Higher elevation low density liquid reservoir. May comprise one or more storage tanks or storage devices. May be atmospheric pressure, or semi-pressurized, or pressurized, or a combination thereof. May be semi-refrigerated or fully refrigerated, or non-refrigerated, or a combination thereof.
2	Pipe transferring low density liquid between a higher elevation low density liquid reservoir and a pump.
3	Pump and / or turbine or Hydraulic Power Recovery Turbine (HPRT)
4	Pipe transferring low density liquid between a pump and a power exchanger, or between higher elevation parts and lower elevation parts, or a combination thereof.
5	Pipe transferring low density liquid between a power exchanger and a lower elevation reservoir.
6	A lower elevation reservoir which may be configured to store both low density liquid and high density liquid.

7	A pressure equalizer, or pressure sensor, or a combination thereof.
8	A pipe transferring high density liquid between a lower elevation reservoir and a power exchanger.
9	A power exchanger. A power exchanger may be located in a lower elevation region near a lower elevation reservoir. A power exchanger may be located between a higher elevation region and a lower elevation region. '9' may comprise a turbine and / or pump which may recover excess pressure in the low density liquid being transferred to a lower elevation reservoir. If desired, 'excess pressure' may be equal to or greater than the power required and / or pressure loss to transfer high density liquid from a lower elevation reservoir to a higher elevation reservoir. '9' may transfer power between a low density liquid stream and a high density liquid stream, which may comprise, including, but not limited to, hydraulic, or electrical, or mechanical, or pneumatic, or a combination thereof power transfer. '9' may be designed to transfer pressure or power or both from low density liquid to high density liquid, or from high density liquid to low density liquid, or to a combination thereof.
10	A pipe transferring high density liquid between a power exchanger and a higher elevation region.
11	A process for separating or removing at least a portion of low density liquid present in the high density liquid.
12	A pipe transferring high density liquid between a process for separating or removing at least a portion of low density liquid present in the high density liquid and a higher elevation high density liquid reservoir.
13	A higher elevation high density liquid reservoir. May comprise one or more storage tanks or storage devices.
14	Separated low density liquid, which may require additional processing before returning to low density liquid in the system.
15	Additional processing for separated low density liquid. For example, if the low density liquid is at a vapor phase, the additional processing may involve compressing, condensing, or cooling the low density liquid before transfer to another part of the system.
16	A pipe transferring low density liquid from a processing step to a low density liquid higher elevation reservoir.
17	May represent the transfer of heat, or fluids, or working fluids, or a combination thereof to facilitate cooling, or heating, or thermal management, or a combination thereof of the low density liquid, or high density liquid, or both.
18	A process for cooling, or heating, or thermal management, or a combination thereof. '18' may employ ocean water or deep-sea ocean water as a heat sink.
Higher Elevation	Label for an adjacent dashed box. Said adjacent dashed box may comprise higher elevation parts.
Lower Elevation	Label for an adjacent dashed box. Said adjacent dashed box may comprise lower elevation parts.

[0616] Figures 145, 146:

Label	Description
1	Higher elevation reservoir configured to store low density liquid and high density liquid. May comprise one or more storage tanks or storage devices. May be

	atmospheric pressure, or semi-pressurized, or pressurized, or a combination thereof. May be semi-refrigerated or fully refrigerated, or non-refrigerated, or a combination thereof.
2	A pipe transferring low density liquid between a higher reservoir and a heat exchanger.
3	A low density liquid – high density liquid heat exchanger. ‘3’ may comprise a counter-current heat exchanger.
4	A pipe transferring low density liquid between a higher reservoir and a pump.
5	A pump and / or turbine or Hydraulic Power Recovery Turbine (HPRT)
6	A pipe transferring low density liquid between a pump and a lower elevation reservoir, or between higher elevation parts and lower elevation parts, or a combination thereof.
7	A lower elevation reservoir which may be configured to store both low density liquid and high density liquid.
8	A pipe transferring high density liquid between a lower elevation reservoir and a heat exchanger, or a pipe transferring high density liquid between lower elevation parts and higher elevation parts, or a combination thereof.
9	A pipe transferring high density liquid between a heat exchanger and a higher elevation reservoir.
10	May represent the transfer of heat, or fluids, or working fluids, or a combination thereof to facilitate cooling, or heating, or thermal management, or a combination thereof of the low density liquid, or high density liquid, or both.
11	A process for cooling, or heating, or thermal management, or a combination thereof. ‘11’ may employ ocean water or deep-sea ocean water as a heat sink.
Higher Elevation	Label for an adjacent dashed box. Said adjacent dashed box may comprise higher elevation parts.
Lower Elevation	Label for an adjacent dashed box. Said adjacent dashed box may comprise lower elevation parts.

[0617] Figure 147:

Label	Description
1	Higher elevation reservoir configured to store low density liquid and high density liquid. May comprise one or more storage tanks or storage devices. May be atmospheric pressure, or semi-pressurized, or pressurized, or a combination thereof. May be semi-refrigerated or fully refrigerated, or non-refrigerated, or a combination thereof.
2	A pipe transferring low density liquid between a higher reservoir and a heat exchanger.
3	A low density liquid – high density liquid heat exchanger. ‘3’ may comprise a counter-current heat exchanger.
4	A pipe transferring low density liquid between a higher reservoir and a pump.
5	A pump and / or turbine or Hydraulic Power Recovery Turbine (HPRT)
6	A pipe transferring low density liquid between a pump and a lower elevation reservoir, or between higher elevation parts and lower elevation parts, or a combination thereof.
7	A lower elevation reservoir which may be configured to store both low density liquid and high density liquid.

8	A pipe transferring high density liquid between a lower elevation reservoir and a heat exchanger, or a pipe transferring high density liquid between lower elevation parts and higher elevation parts, or a combination thereof.
9	A pipe transferring high density liquid between a high density liquid – low density liquid heat exchanger and a supplemental cooling process or supplemental cooling heat exchanger.
10	A supplemental cooling process or supplemental cooling heat exchanger. May further cool or adjust the temperature of the high density liquid to ensure it is within a desired temperature range before entering a higher elevation reservoir.
11	A pipe transferring high density liquid between a cooling process or supplemental cooling heat exchanger and a higher elevation reservoir.
12	May represent the transfer of heat, or fluids, or working fluids, or a combination thereof to facilitate cooling, or heating, or thermal management, or a combination thereof of the low density liquid, or high density liquid, or both.
13	A process for cooling, or heating, or thermal management, or a combination thereof. '13' may employ ocean water or deep-sea ocean water as a heat sink.
14	May represent the transfer of heat, or fluids, or working fluids, or a combination thereof to facilitate cooling, or heating, or thermal management, or a combination thereof of the low density liquid, or high density liquid, or both.
15	A process for cooling, or heating, or thermal management, or a combination thereof. '15' may employ ocean water or deep-sea ocean water as a heat sink.
Higher Elevation	Label for an adjacent dashed box. Said adjacent dashed box may comprise higher elevation parts.
Lower Elevation	Label for an adjacent dashed box. Said adjacent dashed box may comprise lower elevation parts.

[0618] Figures 148 – 151:

Label	Description
1	A higher elevation reservoir configured to store low density liquid. May comprise one or more storage tanks. May be atmospheric pressure, or semi-pressurized, or pressurized, or a combination thereof. May be semi-refrigerated or fully refrigerated, or non-refrigerated, or a combination thereof.
2	A lower elevation reservoir designed to store both low density liquid and high density liquid.
3	Pipe transferring low density liquid between a pump / generator and a lower elevation reservoir.
4	A pump and / or generator.
5	A valve.
6	A higher elevation reservoir configured to store high density liquid. May comprise one or more storage tanks.
7	Pipe transferring high density liquid between a lower elevation reservoir and a higher elevation reservoir.
8	A floating structure which may be employed to contain at least a portion of higher elevation parts or higher elevation region. May comprise an FSO, or FSU, or platform, or ship, or converted structure, or a custom structure, a moored structure, or a stable structure, or a buoyant structure, or a combination thereof. In the

	present figure, '8' may comprise a floating structure configured to store high density liquid.
Ocean	May comprise a water body, such as an ocean or lake. May represent a body of liquid. May represent a body of solid. May represent a combination thereof.
Land	May comprise land or solid surface or a combination thereof.

[0619] Figures 152 – 153:

Label	Description
1	May represent a low density liquid pipe.
2	A rigid storage tank. May represent a lower elevation reservoir, or a higher elevation reservoir, or a combination thereof.
3	May represent a high density liquid pipe.
4	A pipe fluidly connecting a pressure equalizer with a rigid tank.
5	One or more or a combination of components comprising a pressure equalizer. May comprise, including, but not limited to, one or more or combination of the following: a valve, a flow meter, or a flow controller, or a pressure sensor, or a pump, a turbine, or a connector / disconnecter.
6	One or more or a combination of components comprising a pressure equalizer. May comprise, including, but not limited to, one or more or combination of the following: a bladder tank, or a piston, or a variable volume tank, or an expansion tank, or a tank with pressure equilibrium between the fluids surrounding the tank and the fluids inside the tank.

[0620] Figures 154, 155:

Label	Description
1	Higher elevation reservoir configured to store low density liquid and high density liquid. May comprise one or more storage tanks or storage devices. May be atmospheric pressure, or semi-pressurized, or pressurized, or a combination thereof. May be semi-refrigerated or fully refrigerated, or non-refrigerated, or a combination thereof.
2	A pipe transferring low density liquid between a higher reservoir and a heat exchanger.
3	A low density liquid – high density liquid heat exchanger. '3' may comprise a counter-current heat exchanger.
4	A pipe transferring low density liquid between a higher reservoir and a pump.
5	A pump and / or turbine or Hydraulic Power Recovery Turbine (HPRT)
6	A pipe transferring low density liquid between a pump and a power exchanger, or between higher elevation parts and lower elevation parts, or a combination thereof.
7	A power exchanger. A power exchanger may be located in a lower elevation region near a lower elevation reservoir. A power exchanger may be located between a higher elevation region and a lower elevation region. '7' may comprise a turbine and / or pump which may recover excess pressure in the low density liquid being transferred to a lower elevation reservoir. If desired, 'excess pressure' may be equal to or greater than the power required and / or pressure loss to transfer high density liquid from a lower elevation reservoir to a higher elevation reservoir. '7' may transfer power between a low density liquid stream and a high density

	liquid stream, which may comprise, including, but not limited to, hydraulic, or electrical, or mechanical, or pneumatic, or a combination thereof power transfer. '7' may be designed to transfer pressure or power or both from low density liquid to high density liquid, or from high density liquid to low density liquid, or to a combination thereof.
8	Pipe transferring low density liquid between a power exchanger and a lower elevation reservoir.
9	A pressure equalizer, or pressure sensor, or a combination thereof.
10	A lower elevation reservoir which may be configured to store both low density liquid and high density liquid.
11	A pipe transferring high density liquid between a lower elevation reservoir and a power exchanger.
12	A pipe transferring high density liquid between a power exchanger and a heat exchanger, or between lower elevation parts and higher elevation parts, or a combination thereof.
13	A pipe transferring high density liquid between a high density liquid – low density liquid heat exchanger and a supplemental cooling process or supplemental cooling heat exchanger.
14	A supplemental cooling process or supplemental cooling heat exchanger. May further cool or adjust the temperature of the high density liquid to ensure it is within a desired temperature range before entering a higher elevation reservoir.
15	May represent the transfer of heat, or fluids, or working fluids, or a combination thereof to facilitate cooling, or heating, or thermal management, or a combination thereof of the low density liquid, or high density liquid, or both.
16	A process for cooling, or heating, or thermal management, or a combination thereof. '16' may employ ocean water or deep-sea ocean water as a heat sink.
17	A pipe transferring high density liquid between a cooling process or supplemental cooling heat exchanger and a higher elevation reservoir.
18	May represent the transfer of heat, or fluids, or working fluids, or a combination thereof to facilitate cooling, or heating, or thermal management, or a combination thereof of the low density liquid, or high density liquid, or both.
19	A process for cooling, or heating, or thermal management, or a combination thereof. '19' may employ ocean water or deep-sea ocean water as a heat sink.
Higher Elevation	Label for an adjacent dashed box. Said adjacent dashed box may comprise higher elevation parts.
Lower Elevation	Label for an adjacent dashed box. Said adjacent dashed box may comprise lower elevation parts.

[0621] Figures 156, 157:

Label	Description
1	Higher elevation reservoir configured to store low density liquid and high density liquid. May comprise one or more storage tanks or storage devices. May be atmospheric pressure, or semi-pressurized, or pressurized, or a combination thereof. May be semi-refrigerated or fully refrigerated, or non-refrigerated, or a combination thereof.
2	Pipe transferring low density liquid between a higher elevation reservoir and a pump.

3	Pump and / or turbine or Hydraulic Power Recovery Turbine (HPRT)
4	Pipe transferring low density liquid between a pump and a power exchanger, or between higher elevation parts and lower elevation parts, or a combination thereof.
5	A power exchanger. A power exchanger may be located in a lower elevation region near a lower elevation reservoir. A power exchanger may be located between a higher elevation region and a lower elevation region. '5' may comprise a turbine and / or pump which may recover excess pressure in the low density liquid being transferred to a lower elevation reservoir. If desired, 'excess pressure' may be equal to or greater than the power required and / or pressure loss to transfer high density liquid from a lower elevation reservoir to a higher elevation reservoir. '5' may transfer power between a low density liquid stream and a high density liquid stream, which may comprise, including, but not limited to, hydraulic, or electrical, or mechanical, or pneumatic, or a combination thereof power transfer. '5' may be designed to transfer pressure or power or both from low density liquid to high density liquid, or from high density liquid to low density liquid, or to a combination thereof.
6	A pipe transferring low density liquid between a power exchanger and a lower elevation reservoir.
7	A lower elevation reservoir which may be configured to store both low density liquid and high density liquid.
8	A pressure equalizer, or pressure sensor, or a combination thereof.
9	A pipe transferring high density liquid between a lower elevation reservoir and a power exchanger.
10	A pipe transferring high density liquid between a power exchanger and a higher elevation reservoir.
11	May represent the transfer of heat, or fluids, or working fluids, or a combination thereof to facilitate cooling, or heating, or thermal management, or a combination thereof of the low density liquid, or high density liquid, or both.
12	A process for cooling, or heating, or thermal management, or a combination thereof. '12' may employ ocean water or deep-sea ocean water as a heat sink.
Higher Elevation	Label for an adjacent dashed box. Said adjacent dashed box may comprise higher elevation parts.
Lower Elevation	Label for an adjacent dashed box. Said adjacent dashed box may comprise lower elevation parts.

[0622] Figure 158:

Label	Description
1	Higher elevation reservoir which may be configured to store low density liquid and high density liquid. May comprise one or more storage tanks or storage devices. May be atmospheric pressure, or semi-pressurized, or pressurized, or a combination thereof. May be semi-refrigerated or fully refrigerated, or non-refrigerated, or a combination thereof.
2	Pipe transferring low density liquid between a higher elevation reservoir and a pump.
3	Pump and / or turbine or Hydraulic Power Recovery Turbine (HPRT)

4	Pipe transferring low density liquid between a pump and a lower elevation reservoir, or between higher elevation parts and lower elevation parts, or a combination thereof.
5	A lower elevation reservoir which may be configured to store both low density liquid and high density liquid.
6	A pressure equalizer, or pressure sensor, or a combination thereof.
7	A pipe transferring high density liquid between a lower elevation reservoir and a pump.
8	A pump which may be fluidly connected to high density liquid which may provide supplemental pressure to the high density liquid. Said supplemental pressure may be equal to or greater than the pressure difference, pressure loss, or pressure drop required to transfer high density liquid from lower elevation parts to higher elevation parts.
9	A pipe transferring high density liquid between a pump and a higher elevation reservoir, or between lower elevation parts and higher elevation parts.
10	May represent the transfer of heat, or fluids, or working fluids, or a combination thereof to facilitate cooling, or heating, or thermal management, or a combination thereof of the low density liquid, or high density liquid, or both.
11	A process for cooling, or heating, or thermal management, or a combination thereof. '11' may employ ocean water or deep-sea ocean water as a heat sink.
Higher Elevation	Label for an adjacent dashed box. Said adjacent dashed box may comprise higher elevation parts.
Lower Elevation	Label for an adjacent dashed box. Said adjacent dashed box may comprise lower elevation parts.

[0623] Figure 159:

Label	Description
1	Higher elevation reservoir which may be configured to store low density liquid and high density liquid. May comprise one or more storage tanks or storage devices. May be atmospheric pressure, or semi-pressurized, or pressurized, or a combination thereof. May be semi-refrigerated or fully refrigerated, or non-refrigerated, or a combination thereof.
2	Pipe transferring low density liquid between a higher elevation reservoir and a pump.
3	Pump and / or turbine or Hydraulic Power Recovery Turbine (HPRT)
4	Pipe transferring low density liquid between a pump and a lower elevation reservoir, or between higher elevation parts and lower elevation parts, or a combination thereof.
5	A lower elevation reservoir which may be configured to store both low density liquid and high density liquid.
6	A pressure equalizer, or pressure sensor, or a combination thereof.
7	A pipe transferring high density liquid between a lower elevation reservoir and a pump, or between lower elevation parts and higher elevation parts.
8	A pump which may be fluidly connected to high density liquid which may provide supplemental pressure to the high density liquid. Said supplemental pressure may be equal to or greater than the pressure difference, pressure loss, or pressure drop required to transfer high density liquid from higher elevation parts to lower

	elevation parts. Said supplemental pressure may be provided to ensure the pressure of high density liquid in the lower elevation reservoir is about the same as or near the hydrostatic pressure outside of, or surrounding, or adjacent to said lower elevation reservoir.
9	A pipe transferring high density liquid between a pump and a higher elevation reservoir.
10	May represent the transfer of heat, or fluids, or working fluids, or a combination thereof to facilitate cooling, or heating, or thermal management, or a combination thereof of the low density liquid, or high density liquid, or both.
11	A process for cooling, or heating, or thermal management, or a combination thereof. '11' may employ ocean water or deep-sea ocean water as a heat sink.
Higher Elevation	Label for an adjacent dashed box. Said adjacent dashed box may comprise higher elevation parts.
Lower Elevation	Label for an adjacent dashed box. Said adjacent dashed box may comprise lower elevation parts.

Additional Description

- In some embodiments, a pressure exchanger, or pressure recovery, or power recovery turbine, or a combination thereof may be employed, which may be referred to as a power exchanger or a pressure exchanger. Please note, power exchanger and pressure exchanger may be employed interchangeably. In some embodiments, a power exchanger or pressure exchanger may be employed near a lower elevation reservoir.
 - A power exchanger may involve recovering power from one stream and transferring it to another stream. For example, in some embodiments, during charging, excess pressure or power in the low density liquid stream being transferred into a lower elevation reservoir may be harnessed by a power exchanger, and said harnessed power may be employed to power and / or facilitate the transfer a high density liquid from the lower elevation reservoir to the higher elevation reservoir.
 - In some embodiments, energy is stored when low density liquid is transferred in a pipe from a higher elevation reservoir to a lower elevation reservoir, displacing high density liquid in the lower elevation reservoir. In some embodiments, the displaced high density liquid in the lower elevation is transferred in a pipe to a higher elevation reservoir. In some embodiments, the pressure of the low density liquid during storing energy or 'charging' must be greater than the pressure of the high density liquid in the lower elevation reservoir. In some embodiments, the pressure of the low density liquid during storing energy or 'charging' must be greater than the pressure of the high density liquid in the lower elevation reservoir

by a pressure difference greater than or equal to the pressure difference required for displaced high density liquid to transfer through a pipe from the lower elevation reservoir to the higher elevation reservoir at a desired volumetric flow rate. Said desired volumetric flow rate may comprise, for example, a volumetric flow rate equal to the volumetric flow rate of low density liquid being transferred into the lower elevation reservoir. Transferring high density liquid through a pipe from a lower elevation reservoir to a higher elevation reservoir at a sufficient flow rate may require a pressure difference or some pressurization to, for example, overcome pipeline pressure drop. In some embodiments, said pressure difference may be applied by a low density liquid being transferred into a lower elevation reservoir.

- In some embodiments, said pressure difference may be applied by low density liquid being transferred into a lower elevation reservoir and wherein the pressure difference is applied within the lower elevation reservoir to the high density liquid within a lower elevation reservoir. Applying said pressure difference within a lower elevation reservoir may require a lower elevation reservoir designed to withstand a pressure equal to or greater than said pressure difference, especially, for example, if the pressure inside said lower elevation reservoir was about equal to the pressure surrounding or outside or adjacent to said lower elevation reservoir prior to applying said pressure difference.
- In some embodiments, said pressure difference may be powered by low density liquid being transferred into a lower elevation reservoir. For example, before entering a lower elevation reservoir, low density liquid may pass through a power exchanger, wherein a portion of power and / or pressure is recovered from said low density liquid. Said portion of power and / or pressure recovered from said low density liquid may be employed to power the transfer of high density liquid from a lower elevation reservoir to a higher elevation reservoir. Said 'power the transfer of high density liquid from a lower elevation reservoir to a higher elevation reservoir' may involve providing pressure and / or power to a pump to pressurize the high density liquid to a pressure difference greater than or equal to the pressure difference required for

displaced high density liquid to transfer through a pipe from the lower elevation reservoir to the higher elevation reservoir at a desired volumetric flow rate. It may be desirable for a power exchange or pressure exchange or both to occur outside of a lower elevation tank or reservoir. For example, by conducting at least a portion of said power exchange or pressure exchange or both outside a lower elevation tank or reservoir, said lower elevation tank or reservoir may operate with minimal pressure internal pressure change during charging and discharging. For example, by conducting at least a portion of said power exchange or pressure exchange or both outside a lower elevation tank or reservoir, said lower elevation tank or reservoir may require less pressure difference tolerance or pressure difference resistance, which may enable the use of larger and / or less expensive tanks or other storage vessels.

- In some embodiments, a power exchanger may function as a flow meter, or a flow controller, or a valve, or a combination thereof. For example, in some embodiments, a power exchanger may communicate with a pressure sensor and / or pressure equalizer inside a lower elevation reservoir, wherein said power exchanger may adjust the flow rate of low density liquid and / or high density liquid, for example, to ensure the pressure inside the lower elevation reservoir is within a desired pressure range.
- In some embodiments, a power exchanger may function to provide power to processes near a lower elevation reservoir. Said processes near a lower elevation reservoir may include, but are not limited to, valves, flow controllers, sensors, monitoring equipment, pumps, pressure exchangers, turbines, flow meters, lights, equipment, drones, autonomous vehicles, non-autonomous vehicles, communication devices, or a combination thereof.
- The pressure of the low density liquid created by a pump during storing energy or ‘charging’ may be equal to or greater than, for example, the sum of:
 - The gravitational or hydrostatic pressure of the high density liquid minus the gravitational or hydrostatic pressure of the low density liquid at the elevation difference between the lower elevation reservoir and the higher elevation reservoir.

- The pressure difference or pressure loss of low density liquid during transfer in a pipeline between a higher elevation reservoir and a lower elevation reservoir at a desired volumetric flow rate
 - The pressure difference or pressure loss of high density liquid during transfer in a pipeline between a lower elevation reservoir and a higher elevation reservoir at a desired volumetric flow rate.
 - Any pressure or power losses in the exchange of power or pressure between low density liquid and high density liquid to, for example, enable or facilitate low density liquid displacing high density liquid in a lower elevation reservoir.
- In some embodiments, a portion of low density liquid may dissolve in high density liquid. In some embodiments, a portion of high density liquid may dissolve in low density liquid. In some embodiments, a portion of low density liquid may dissolve in high density liquid due to the signification pressure of low density liquid and high density liquid in a lower elevation reservoir. In some embodiments, low density liquid may possess a low boiling point or a high vapor pressure or both. In some embodiments, low density liquid may be present in high density liquid transferred from a lower elevation reservoir to a higher elevation reservoir. In some embodiments, before transferring said high density liquid into a higher elevation reservoir, a portion of said low density liquid present in the high density liquid may be removed from said high density liquid. In some embodiments, a portion of said low density liquid present in the high density liquid may be removed from said high density liquid while said high density liquid is inside a higher elevation reservoir. Said removing of a portion of said low density liquid from said high density liquid may involve, for example, including, but not limited to, one or more or a combination of the following: depressurization, liquid-liquid separation, gas-liquid separation, vacuum distillation, vacuum compression, degasification, agitation, heating, cooling, compression, membranes, or separators. Separated low density liquid may be recovered and may be transferred to another portion of the process, or may be transferred to another application. Separated low density liquid may comprise vapor phase low density liquid. Said vapor phase low density liquid may be compressed and / or condensed and / or cooled before or during or after transfer to another portion of the process. Separation of low density liquid present in high density liquid may occur before, or during, or after, or a combination thereof transferring high density liquid into a higher elevation reservoir.

- In some embodiments, low density liquid may be dissolved in high density liquid at a concentration less than 30wt%, or 20wt%, or 10wt%, or 5wt%, or 4wt%, or 3wt%, or 2wt%, or 1wt%, or 0.5wt%, or 0.1wt%, or 0.01wt%, or 0.001 wt%.
- In some embodiments, low density liquid and / or high density liquid may be thermally managed to be stored at a desired temperature range in a higher elevation reservoir. For example, if a higher elevation reservoir is configured to store both low density liquid and high density liquid, low density liquid and high density liquid may be cooled or heated or both to ensure a desired temperature range. For example, if low density liquid is liquid normal butane and high density liquid is ocean water or an aqueous solution with similar density as ocean water, it may be desirable for low density liquid or high density liquid or both to be stored at a temperature near the temperature of deep ocean water (for example: less than 6 degrees Celsius), or at a temperature near or less than or equal to the boiling point of low density liquid at atmospheric pressure (for example: less than or equal to 1°C or -1°C), or both. Due to, for example, the large mass of the low density liquid and high density liquid, and / or the low surface area to volume ratio of large volume tanks, and / or the mild or cold temperature of deep ocean water, the temperature of low density liquid and high density liquid may operate within a desired temperature range or with minimal temperature change during process operation. If the temperature of low density liquid and / or high density liquid changes beyond a desired temperature range, a thermal management process may cool and / or heat the low density liquid and / or high density liquid into a desired temperature range.
- In some embodiments, a lower elevation region or a lower elevation reservoir may comprise tanks in different locations.
- In some embodiments, a higher elevation region or a higher elevation reservoir may comprise tanks in different locations. For example, in some embodiments, a higher elevation lower density liquid tank may be located on land, while a higher elevation higher density liquid tank may comprise a floating structure. For example, in some embodiments, a higher elevation lower density liquid tank may comprise a rigid tank while a higher elevation higher density liquid tank may comprise bladder tank. For example, in some embodiments, a higher elevation lower density liquid tank may comprise a rigid tank while a higher elevation higher density liquid tank may comprise a water storage pond or basin. For example, in some embodiments, a higher elevation higher density liquid tank may comprise a floating structure.

- In some embodiments, a rigid tank may be employed as a lower elevation reservoir. If a lower elevation reservoir is located underwater, it may be desirable for the pressure inside the lower elevation reservoir to be similar to the pressure surrounding or outside said underwater reservoir. It may be desirable for the pressure inside the lower elevation reservoir to be similar to the pressure surrounding or outside a lower elevation reservoir to, for example, minimize the required pressure difference resistance or required pressure difference tolerance of a lower elevation reservoir tank, which may minimize the cost of a lower elevation reservoir tank. It may be desirable for the lower elevation reservoir to be able to mitigate or minimize the impact of changes in pressure or pressure waves due to, for example, changes in the flow of liquids, or due to overpressure, or due to water hammer, or due to liquid hammer, or a combination thereof. For example, some embodiments may employ a pressure equalizer interconnected to a lower elevation reservoir rigid tank. A pressure equalizer may comprise a relatively small bladder tank, and / or a piston, and / or a flow meter, and / or a pressure sensor, and / or a flow controller, and / or actuator, and / or pump, and / or a valve, and / or pressure relief valve, and / or pressure compensation valve, or a combination thereof.
 - A pressure equalizer may ensure the pressure inside a lower elevation reservoir is similar to or about the same as the pressure outside, or surrounding, or adjacent to a lower elevation reservoir.
 - A pressure equalizer may be fluidly connected to high density liquid inside a rigid lower elevation reservoir. Alternatively, or additionally, A pressure equalizer may be fluidly connected to low density liquid inside a rigid lower elevation reservoir.
 - If a pressure equalizer employs a bladder tank, or a piston, or a combination thereof, it may be desirable for the volumetric capacity of said bladder tank, or a piston, or a combination thereof to be less than or equal to 0.01%, or 0.05%, or 0.1%, or 0.5%, or 1%, or 5%, or 10%, or 15%, or 20%, or 25%, the volumetric capacity of the rigid lower elevation reservoir.
 - A pressure equalizer may mitigate or minimize the impact of changes in pressure or pressure waves
 - A pressure equalizer may monitor pressure inside a rigid tank relative to the pressure outside a rigid tank. For example, if liquid flows from the pressure equalizer into a lower elevation reservoir, the pressure inside a lower elevation

reservoir may be less than the pressure outside a lower elevation reservoir. For example, if liquid flows from a lower elevation reservoir into a pressure equalizer, the pressure inside a lower elevation reservoir may be greater than the pressure outside a lower elevation reservoir.

- A pressure equalizer may communicate with pumps, or power exchangers, or valves, or flow controllers, or other equipment, or a combination thereof which may be located in a lower elevation region, or a higher elevation region, or any other point within the system, or a combination thereof. For example, a pressure equalizer may provide information on the pressure or relative pressure inside a lower elevation reservoir, which may enable other equipment to make adjustments to ensure a rigid lower elevation reservoir is at a desired pressure relative to the pressure surrounding or adjacent to or outside of said rigid lower elevation reservoir.
- A pressure equalizer bladder tank or piston or a combination thereof may be located in a location external to a rigid tank.
- A pressure equalizer bladder tank or piston or a combination thereof may be configured such that the bladder tank or piston or a combination thereof can be replaced or removed if desired. For example, a bladder tank or piston or a combination thereof may be removed or replaced if damaged, or requiring maintenance, or due to an improved alternative, or a combination thereof.
- A pressure equalizer bladder tank or piston or a combination thereof may be configured such that the bladder tank or piston or a combination thereof is accessible to subsea watercraft or autonomous vehicles.
- A pressure equalizer bladder tank or piston or a combination thereof may be configured such that the bladder tank or piston or a combination thereof may be configured to be easily isolatable from the rigid tank. For example, a pressure equalizer bladder tank or piston or a combination may be fluidly disconnected from a rigid tank by closing a valve. A pressure equalizer bladder tank or piston or a combination may be fluidly disconnected, for example, including, but not limited to, in the event of a leak, or in the event of a potential risk of a failure, or if the pressure equalizer is being maintained, or if parts of the pressure equalizer are being replaced, or a combination thereof

- It may be desirable for a pressure equalizer bladder and / or piston to be at a state of partially utilized capacity under normal operating conditions. By being at a state of partially utilized capacity, overpressure events may be mitigated due to the flow of liquid into the pressure equalizer due to the spare capacity in the pressure equalizer. By being at a state of partially utilized capacity, underpressure events may be mitigated due to the flow of liquid from the pressure equalizer into the lower elevation rigid tank.
- It may be desirable for relatively minimal liquid to flow into or out of a pressure equalizer bladder and / or piston during normal operation of the energy storage process. For example, during a normal full charge/discharge cycle of the energy storage process, the volume of liquid stored in a pressure equalizer bladder and / or piston may only change by less than or equal to $\pm 1\%$, or $\pm 5\%$, or $\pm 10\%$, or $\pm 15\%$, or $\pm 20\%$, or $\pm 25\%$, or $\pm 30\%$, or $\pm 35\%$, or $\pm 40\%$, or $\pm 45\%$, or $\pm 50\%$, or $\pm 55\%$, or $\pm 60\%$, or $\pm 65\%$, or $\pm 70\%$, or $\pm 75\%$, or $\pm 80\%$, or $\pm 85\%$, or $\pm 90\%$.
- It may be desirable for the pressure equalizer to only be fluidly connected with liquid in a lower elevation reservoir during overpressure and / or underpressure events. For example, in an overpressure event, a pressure release or similar valve may open to allow liquid to transfer from a rigid lower elevation reservoir into a pressure equalizer. For example, in an underpressure event, a valve may open to allow liquid to transfer from a pressure equalizer into a rigid lower elevation reservoir.

Description

[0624] Energy can be stored by pumping low density liquid into a lower elevation reservoir to displace high density liquid in the lower elevation reservoir. In some embodiments, the density of the high density liquid is similar or about the same as the density of ocean water or water or other liquid surrounding or adjacent to the lower elevation reservoir. Advantageously, using a high density liquid with a density similar to or about the same as ocean water or liquid surrounding or adjacent to the lower elevation reservoir may enable the pressure inside the lower elevation reservoir to be the same or similar to the pressure surrounding or adjacent to the lower elevation reservoir because the density of the high density liquid inside the system may be about the same as the liquid adjacent to or surrounding the tank, which may enable a similar hydrostatic pressure. By having similar hydrostatic pressure inside and outside of a lower elevation reservoir, the lower

elevation reservoir may require minimal pressure resistance or pressure difference resistance significantly less than the pressure difference between the lower elevation and higher elevation tanks, which may enable the use of lower cost and / or larger volume tanks. A potential challenge of some embodiments of the presently described process is the process may be limited to liquids with a density similar to ocean water. If the density of the higher density liquid in some embodiments of the presently described process is greater than the density ocean water, hydrostatic pressure of the higher density liquid may be greater than the hydrostatic pressure of the ocean water at the depth of the lower elevation reservoir, which may result in the requirement of using a tank resistant to the pressure difference between the hydrostatic pressure of the higher density liquid and ocean water in the lower elevation reservoir, which may be significantly more expensive than a tank with pressure equilibrium with the surrounding ocean water. It may be desirable to employ a high density liquid with a higher density than ocean water due to, for example, the greater system energy density which may result. The energy density per cubic meter of liquid in some embodiments is driven by the density difference between the low density liquid and the high density liquid. Increasing the density of the high density liquid may substantially increase the energy density of the system by increasing the density difference between the low density liquid and the high density liquid. It may be desirable to develop a system which stores power by displacing high density liquid with a low density liquid, wherein the higher density liquid has a density greater than ocean water or greater than the density of water adjacent to the lower elevation reservoir, and wherein the lower elevation reservoir may operate at a pressure in pressure equilibrium or similar to the pressure of surrounding or adjacent ocean water. It may be desirable to develop a system which benefits from the greater system energy density of employing a liquid with a density greater than ocean water, while also enabling the lower elevation reservoir to operate at pressure equilibrium with the adjacent ocean water.

[0625] In some embodiments, the higher elevation reservoir may be located near land at an elevation greater than the elevation of the surface of a water body or the elevation of the ocean surface. In some embodiments, the higher elevation reservoir itself may be located at an elevation greater than the elevation of a water body or the elevation of the ocean surface. For example, the higher elevation reservoir may comprise a structure or tank located at an elevation, at least in part, above the elevation of a water body or the elevation of the ocean surface. For example, the higher elevation reservoir may be located on a mountain, or hill, or platform, or floating structure, or a similarly elevated surface, or a combination thereof. In some embodiments, it may be desirable to locate the higher elevation reservoir of the high density liquid at a higher elevation than the higher

elevation reservoir of the low density liquid. For example, it may be desirable to locate the higher elevation reservoir of the low density liquid at an elevation near sea-level, while the higher elevation reservoir of the high density liquid may be located greater than 10 meters, or greater than 25 meters, or greater than 50 meters, or greater than 75 meters, or greater than 100 meters, or greater than 125 meters, or greater than 150 meters above sea level.

- In some embodiments, placing the high density liquid higher elevation reservoir at an elevation greater than the elevation of the ocean surface, or greater than the elevation of the higher elevation low density liquid reservoir, or a combination thereof may be employed to ensure the hydrostatic pressure inside the lower elevation reservoir is the same or similar to the hydrostatic pressure adjacent to the lower elevation reservoir. If, for example, the high density liquid has a density less than ocean water, it may be desirable to increase elevation of high density liquid higher elevation reservoir to match hydrostatic pressure of ocean water adjacent to the lower elevation reservoir. For example, some embodiments may employ freshwater or freshwater with corrosion and biofouling inhibitors as the high density liquid, and the freshwater high density liquid may possess a density less than ocean water. For example, the density of ocean water may be 1.035 g/mL while the density of corrosion and biofouling inhibited freshwater may be 1.01 g/mL. If the lower elevation reservoir is located at an ocean water depth of 2,500 meters and the high density liquid higher elevation reservoir is located at sea-level, the hydrostatic pressure difference between the ocean water and the high density liquid if the high density liquid comprises inhibited freshwater with 1.01 g/mL density is equivalent to a hydraulic head of 62.5 meters. For example, in the present instance it may be desirable to place the higher elevation high density liquid reservoir 62.5 meters above sea level if the high density liquid comprises inhibited freshwater with 1.01 g/mL density.
- In some embodiments, placing the high density liquid higher elevation reservoir at an elevation greater than the elevation of the ocean surface, or greater than the elevation of the higher elevation low density liquid reservoir, or a combination thereof may be employed to increase the system energy density per cubic meter of energy or electricity stored. By increasing the elevation of the higher elevation high density liquid reservoir, the energy density of the system may increase. In some embodiments, increasing the elevation of the high density liquid reservoir above sea level may result in the lower elevation reservoir possessing a hydrostatic pressure inside greater than the hydrostatic pressure adjacent to the lower elevation reservoir, which may require the use of a tank

resistant to this hydrostatic pressure difference, which may be expensive. It may be desirable to develop a system which benefits from the greater system energy density of a higher elevation high density liquid reservoir at an elevation greater than the surface of an ocean or a water body, while also enabling the lower elevation reservoir to operate at pressure equilibrium with the adjacent ocean water.

Summary Description

[0626] Some embodiments of the present invention may pertain to systems and methods for enabling the use of a high density liquid with a density greater than ocean water while enabling the lower elevation reservoir to remain at or near pressure equilibrium with ocean water or water adjacent to the lower elevation reservoir.

[0627] Some embodiments of the present invention may pertain to systems and methods for enabling the use of higher elevation reservoir located above sea level or above the elevation of the surface of a water body while enabling the lower elevation reservoir to remain at or near pressure equilibrium with ocean water or water adjacent to the lower elevation reservoir.

[0628] Some embodiments of the present invention may pertain to systems and methods for minimizing corrosion or preventing corrosion. For example, some embodiments of the present invention may relate to employing systems for removing dissolved oxygen from high density liquid, or low density liquid, or both to minimize or practically eliminate corrosion on system equipment due to, for example, the low density liquid, or high density liquid, or both inside the system.

Example Figure Descriptions

[0629] Figure 160: A process for storing energy by displacing a high density liquid with a low density liquid. The present embodiment may comprise a higher elevation reservoir configured for storing low density liquid, or higher elevation reservoir configured for storing low density liquid and high density liquid, or a higher elevation reservoir configured for storing high density liquid, or a pump, or a turbine, or a power recovery or pressure recovery system, or a lower elevation reservoir configured to store high density liquid, or a lower elevation reservoir configured to store low density liquid, or a lower elevation reservoir configured to store low density liquid and high density liquid, or pipes interconnecting one or more components, or sensors, or a pressure equalizer, or a combination thereof. The present embodiment may employ a pressure recovery or power recovery system to, for example, enable the lower elevation reservoir to operate at or near pressure equilibrium with the pressure outside of, or surrounding, or adjacent to said lower

elevation reservoir. The lower elevation reservoir may be surrounded by or adjacent to ocean water, water, or air, or a gas, or a solid, or ground, or a combination thereof.

- Charging may involve pumping (for example, '3') a low density liquid from a higher elevation reservoir (for example, '1') to a lower elevation region, where power from the low density liquid may be recovered (for example, '5') to displace at least a portion of a high density liquid in a lower elevation reservoir (for example, '7') and transfer (for example, '10') the high density liquid to a higher elevation reservoir (for example, '1' or '11'). During charging, pressure recovery may involve recovering at least a portion of the pressure in excess of the pressure adjacent to the lower elevation region or lower elevation reservoir or both from the low density liquid (for example, '4') and providing or transferring this pressure or power to the high density liquid (for example, '10'). After or during pressure recovery, the low density liquid may be transferred (for example, '6') into the lower elevation reservoir at or near the pressure of the lower elevation reservoir, or at or near the pressure adjacent to the lower elevation reservoir, or both. Before or while receiving the recovered power or pressure from the low density liquid due to the power or pressure exchanger, a high density liquid may be removed (for example, '9') from the lower elevation reservoir (for example, '7'). After or while receiving the recovered power or pressure from the low density liquid due to the power or pressure exchanger, a high density liquid may be transferred (for example, '10') from the lower elevation region to a higher elevation reservoir (for example, either '1' or '11').
- Discharging may involve allowing a high density liquid from a higher elevation reservoir (for example, '1' or '11') transfer to a lower elevation region, where power from the high density liquid may be recovered (for example, '5') to displace at least a portion of a low density liquid in a lower elevation reservoir (for example, '7') and transfer this low density liquid to a turbine (for example, '3'), generating power. During discharging, pressure recovery may involve recovering at least a portion of the pressure in excess of the pressure adjacent to the lower elevation region or lower elevation reservoir or both from the high density liquid (for example, '10') and providing or transferring this pressure or power to the low density liquid (for example, '4'). After or during pressure recovery, the high density liquid may be transferred (for example, '9') into the lower elevation reservoir at or near the pressure of the lower elevation reservoir, or at or near the pressure adjacent to the lower elevation reservoir, or both. Before or while receiving the recovered power or pressure from the high density liquid due to the power or pressure exchanger, a low density

liquid may be removed (for example, '6') from the lower elevation reservoir (for example, '7'). After or while receiving the recovered power or pressure from the high density liquid due to the power or pressure exchanger, a low density liquid may be transferred (for example, '4') from the lower elevation region to a turbine in a higher elevation reservoir (for example, either '3'). The turbine may generate power from the low density liquid before or while the low density liquid is transferred (for example, '2') to a higher elevation reservoir (for example, '1').

[0630] Figure 161: The present figure may be the same as Figure 160, except the present figure may show an embodiment generating energy or 'discharging'.

[0631] Figure 162: The present figure may be the same as Figure 160, except the low density liquid higher elevation reservoir may be different than the high density liquid higher elevation reservoir. In some embodiments, the low density liquid higher elevation reservoir may be at about the same elevation as the high density liquid higher elevation reservoir. In some embodiments, the low density liquid higher elevation reservoir may be at a higher elevation than the high density liquid higher elevation reservoir. In some embodiments, the low density liquid higher elevation reservoir may be at a lower elevation than the high density liquid higher elevation reservoir. The present figure may show an embodiment storing energy or 'charging'.

[0632] Figure 163: The present figure may be the same as Figure 162, except the present figure may show an embodiment generating energy or 'discharging'.

[0633] Figure 164: The present figure may be the same as Figure 162, except the present figure may show an embodiment with a lower elevation reservoir comprising separate a separate reservoir for low density liquid and a separate reservoir for high density liquid. The present figure may show an embodiment storing energy or 'charging'.

[0634] Figure 165: The present figure may be the same as Figure 164, except the present figure may show an embodiment generating energy or 'discharging'.

Example Figure Keys

Example Figure Key for Figures 160, 161, 162, and 163	
Label	Description
1	Higher elevation reservoir configured to store low density liquid and / or high density liquid. May comprise one or more storage tanks or storage devices. May be atmospheric pressure, or semi-pressurized, or pressurized, or a combination thereof. May be semi-refrigerated or fully refrigerated, or non-refrigerated, or a combination thereof.
2	Pipe transferring low density liquid between a higher elevation reservoir and a pump.
3	Pump and / or turbine or Hydraulic Power Recovery Turbine (HPRT)

4	Pipe transferring low density liquid between a pump and a power exchanger, or between higher elevation parts and lower elevation parts, or a combination thereof.
5	'5' may comprise a power exchanger or pressure exchanger. '5' may be located in a lower elevation region near a lower elevation reservoir. A power exchanger may be located between a higher elevation region and a lower elevation region. '5' may be designed to transfer pressure or power or both from low density liquid to high density liquid, or from high density liquid to low density liquid, or to a combination thereof. '5' may involve recovering pressure in excess of the hydrostatic pressure of ocean water adjacent to the lower elevation reservoir. Said recovered pressure may be transferred to the opposing liquid, providing said power to the opposing liquid while enabling the lower elevation reservoir to operate at or near pressure equilibrium with the pressure or hydrostatic pressure adjacent to the lower elevation reservoir.
6	A pipe transferring low density liquid between a power exchanger and a lower elevation reservoir.
7	A lower elevation reservoir which may be configured to store both low density liquid and high density liquid.
8	A pressure equalizer, or pressure sensor, or a combination thereof. '8' may enable the liquid inside '7' to be at pressure equilibrium with the pressure or hydrostatic pressure adjacent to '7'. '8' may communicate with '5' to ensure '5' is recovering the required pressure to ensure '7' is at or near pressure equilibrium with the with the pressure or hydrostatic pressure adjacent to '7'.
9	A pipe transferring high density liquid between a lower elevation reservoir and a power exchanger.
10	A pipe transferring high density liquid between a power exchanger and a higher elevation reservoir.
11	A higher elevation high density liquid reservoir. In some embodiments, '11' may be located at an elevation different than the elevation of the low density liquid higher elevation reservoir. In some embodiments, '11' may be located at an elevation greater than the elevation of the low density liquid higher elevation reservoir.
Higher Elevation #1	A higher elevation region with an elevation greater than the elevation of the 'Lower Elevation' region and an elevation different than the elevation of the 'Higher Elevation #2' region.
Higher Elevation #2	A higher elevation region with an elevation greater than the elevation of the 'Lower Elevation' region and an elevation different than the elevation of the 'Higher Elevation #1' region.
Higher Elevation	Label for an adjacent dashed box. Said adjacent dashed box may comprise higher elevation parts.
Lower Elevation	Label for an adjacent dashed box. Said adjacent dashed box may comprise lower elevation parts.

Example Pressures in an Example Embodiment

[0635] Example Pressures in an Example Embodiment with High Density Liquid with Density Greater than Ocean Water (Reference Figures 160 and 161)

- In the present example, the elevation of the 'Higher Elevation' region may be about 0 meters above ocean-level, while the elevation of the lower elevation region may be greater than 2500 meters below ocean-level, creating an elevation difference between the lower elevation reservoir and the higher elevation reservoir equal to about 2,500 meters.
- In the present example, the density of the high density liquid may be 1.30 g/mL and the high density liquid may comprise an aqueous solution of calcium chloride.
- In the present example, the density of the low density liquid may be 0.573 g/mL and the low density liquid may comprise normal butane or n-butane.
- In the present example, the density of ocean water may be 1.035 g/mL
- Based on the above, the following are example pressures in Figures 160 and / or 161 for the present example:
 - The pressure of '1' and '2' may be near atmospheric pressure or near the vapor pressure of normal butane. For example, the pressure inside '1' and '2' may be less than or equal to 5 Bar, or 4 Bar, or 3 Bar, or 2 Bar, or 1 Bar, or a combination thereof.
 - The pressure of '4' may vary with water depth. The pressure of '4' may increase with water depth, reaching a maximum pressure near '5' or near or in the 'lower elevation' region. Near '5', the pressure of '4' may be equal to or greater than the hydrostatic pressure of the high density liquid in '10' when the system is storing power or 'charging', as shown in, for example, Figure 160. Near '5', the pressure of '4' may be equal to or less than the hydrostatic pressure of the high density liquid in '10' when the system is generating power or 'discharging', as shown in, for example, Figure 161. The pressure of '4' near '5' may be less than or equal to or greater than or equal to or both a pressure of 325 Bar.
 - The pressure of '6' may be about equal to the pressure of '7' and / or the hydrostatic pressure of ocean water adjacent to '7'. The pressure of '6' may be slightly greater than the pressure of '7' and / or the hydrostatic pressure of ocean water adjacent to '7' during storing of energy or 'charging', as shown in, for example, Figure 160. The pressure of '6' may be slightly less than the pressure of '7' and / or the hydrostatic pressure of ocean water adjacent to '7' during generating of energy or 'discharging', as shown in, for example, Figure 161. The pressure of '6' may be less than or equal to, or greater than or equal to, or a combination thereof a pressure of 258.75 Bar.

- The pressure of '7' may be about the same as the hydrostatic pressure of ocean water adjacent to '7'. The pressure of '7' may be less than or equal to or greater than or equal to or a combination thereof a pressure of 258.75 Bar.
- The pressure of '8' may be about the same as the hydrostatic pressure of ocean water adjacent to '8'. The pressure of '8' may be less than or equal to or greater than or equal to or a combination thereof a pressure of 258.75 Bar.
- The pressure of '9' may be about equal to the pressure of '7' and / or the hydrostatic pressure of ocean water adjacent to '7'. The pressure of '9' may be slightly less than the pressure of '7' and / or the hydrostatic pressure of ocean water adjacent to '7' during storing of energy or 'charging', as shown in, for example, Figure 160. The pressure of '9' may be slightly greater than the pressure of '7' and / or the hydrostatic pressure of ocean water adjacent to '7' during generating of energy or 'discharging', as shown in, for example, Figure 161. The pressure of '9' may be less than or equal to or greater than or equal to or both a pressure of 258.75 Bar.
- The pressure of '10' may vary with water depth. The pressure of '10' may increase with water depth, reaching a maximum pressure near '5' or near or in the 'lower elevation' region. Near '5', the pressure of '10' may be equal to or less than the pressure of the low density liquid in '4' at the same elevation when the system is storing power or 'charging', as shown in, for example, Figure 160. Near '5', the pressure of '10' may be equal to or greater than the pressure of the low density liquid in '4' when the system is generating power or 'discharging', as shown in, for example, Figure 161. The pressure of '10' near '5' may be less than or equal to, or greater than or equal to, or a combination thereof a pressure of 325 Bar.
- The pressure of ocean water adjacent to the 'lower elevation' region may be at a pressure of about 258.75 Bar.
- The power recovery or pressure recovery process ('5') may recover pressure in excess of the hydrostatic pressure adjacent to or outside the lower elevation region in one liquid stream (e.g. '4' or '10') and transfer this power or pressure to the other liquid stream (e.g. '10' or '4').
 - For example, the pressure of the low density liquid in '4' near '5' may be greater than 325 Bar during charging. '5' may recover pressure or

power of greater than or equal to 66.25 Bar from '4' and transfer said recovered pressure or power to '10'. After pressure recovery, the low density liquid ('6') may be transferred into the lower elevation reservoir at a pressure near the pressure of the lower elevation reservoir and / or the hydrostatic pressure of ocean water adjacent to the lower elevation reservoir, or at a pressure of about 258.75 Bar.

- In some embodiments, a pressure exchanger or power exchanger enables the lower elevation reservoir to operate at equilibrium with the pressure surrounding or adjacent to the lower elevation reservoir, regardless of the densities of the lower density liquid and / or higher density liquid.

[0636] Example Pressures in an Example Embodiment with High Density Liquid Higher Elevation Reservoir at Elevation Greater than Sea-Level, or at an Elevation Greater than the Low Density Liquid Higher Elevation Reservoir, or a Combination Thereof (Reference Figures 162 and 163)

- In the present example, the elevation of 'Higher Elevation #1' region may be about 0 meters above ocean-level.
- In the present example, the elevation of 'Higher Elevation #2' region may be about 300 meters above ocean-level.
- In the present example, the elevation of the lower elevation region may be 2500 meters below ocean-level
- In the present example, the density of the high density liquid may be 1.035 g/mL and the high density liquid may comprise an aqueous solution of calcium chloride.
- In the present example, the density of the low density liquid may be 0.573 g/mL and the low density liquid may comprise normal butane or n-butane.
- In the present example, the density of ocean water may be 1.035 g/mL
- Based on the above, the following are example pressures in Figures 162 and / or 163 for the present example:
 - The pressure of '1', or '2', or '11', or a combination thereof may be near atmospheric pressure or near the vapor pressure of normal butane. For example, the pressure inside '1' and '2' may be less than or equal to 5 Bar, or 4 Bar, or 3 Bar, or 2 Bar, or 1 Bar, or a combination thereof.

- The pressure of '4' may vary with water depth. The pressure of '4' may increase with water depth, reaching a maximum pressure near '5' or near or in the 'lower elevation' region. Near '5', the pressure of '4' may be equal to or greater than the hydrostatic pressure of the high density liquid in '10' when the system is storing power or 'charging', as shown in, for example, Figure 162. Near '5', the pressure of '4' may be equal to or less than the hydrostatic pressure of the high density liquid in '10' when the system is generating power or 'discharging', as shown in, for example, Figure 163. The pressure of '4' near '5' may be less than or equal to or greater than or equal to or both a pressure of 289.8 Bar.
- The pressure of '6' may be about equal to the pressure of '7' and / or the hydrostatic pressure of ocean water adjacent to '7'. The pressure of '6' may be slightly greater than the pressure of '7' and / or the hydrostatic pressure of ocean water adjacent to '7' during storing of energy or 'charging', as shown in, for example, Figure 162. The pressure of '6' may be slightly less than the pressure of '7' and / or the hydrostatic pressure of ocean water adjacent to '7' during generating of energy or 'discharging', as shown in, for example, Figure 163. The pressure of '6' may be less than or equal to, or greater than or equal to, or a combination thereof a pressure of 258.75 Bar.
- The pressure of '7' may be about the same as the hydrostatic pressure of ocean water adjacent to '7'. The pressure of '7' may be less than or equal to or greater than or equal to or a combination thereof a pressure of 258.75 Bar.
- The pressure of '8' may be about the same as the hydrostatic pressure of ocean water adjacent to '8'. The pressure of '8' may be less than or equal to or greater than or equal to or a combination thereof a pressure of 258.75 Bar.
- The pressure of '9' may be about equal to the pressure of '7' and / or the hydrostatic pressure of ocean water adjacent to '7'. The pressure of '9' may be slightly less than the pressure of '7' and / or the hydrostatic pressure of ocean water adjacent to '7' during storing of energy or 'charging', as shown in, for example, Figure 162. The pressure of '9' may be slightly greater than the pressure of '7' and / or the hydrostatic pressure of ocean water adjacent to '7' during generating of energy or 'discharging', as shown in, for example, Figure 163. The pressure of '9' may be less than or equal to or greater than or equal to or both a pressure of 258.75 Bar.

- The pressure of '10' may vary with water depth. The pressure of '10' may increase with water depth, reaching a maximum pressure near '5' or near or in the 'lower elevation' region. Near '5', the pressure of '10' may be equal to or less than the pressure of the low density liquid in '4' at the same elevation when the system is storing power or 'charging', as shown in, for example, Figure 162. Near '5', the pressure of '10' may be equal to or greater than the pressure of the low density liquid in '4' when the system is generating power or 'discharging', as shown in, for example, Figure 163. The pressure of '10' near '5' may be less than or equal to, or greater than or equal to, or a combination thereof a pressure of 289.8 Bar.
- The pressure of ocean water adjacent to the 'lower elevation' region may be at a pressure of about 258.75 Bar.
- The power recovery or pressure recovery process ('5') may recover pressure in excess of the hydrostatic pressure adjacent to or outside the lower elevation region in one liquid stream (e.g. '4' or '10') and transfer this power or pressure to the other liquid stream (e.g. '10' or '4').
 - For example, the pressure of the low density liquid in '4' near '5' may be greater than 289.8 Bar during charging. '5' may recover pressure or power of greater than or equal to 31.05 Bar from '4' and transfer said recovered pressure or power to '10'. After pressure recovery, the low density liquid ('6') may be transferred into the lower elevation reservoir at a pressure near the pressure of the lower elevation reservoir and / or the hydrostatic pressure of ocean water adjacent to the lower elevation reservoir, or at a pressure of about 258.75 Bar.
 - In some embodiments, a pressure exchanger or power exchanger enables the lower elevation reservoir to operate at equilibrium with the pressure surrounding or adjacent to the lower elevation reservoir, regardless of the of the hydrostatic pressure of the higher density liquid, or the hydrostatic pressure of the lower density liquid, or both.

Example Exemplary Embodiments

1. A system for storing and generating power comprising:
 - a first storage reservoir near the surface of a body of water and configured to store a fluid which has a lower density than water;

a second storage reservoir located below the surface of the body of water and configured to store a fluid which has a higher density than water;

a pump; and

a generator;

wherein the pump, generator, and the first and second reservoir are operatively connected such that power is stored by displacing the fluid which has a higher density than water in the second storage reservoir by pumping the fluid which has a lower density than water in the first storage reservoir to the second storage reservoir and power is generated or discharged by allowing the fluid which has a lower density than water in the second storage reservoir to return to the first storage reservoir; and

wherein the fluid which has a higher density than water is in liquid form.

2. The system of embodiment 1 wherein the fluid which has a lower density than water is in liquid form.

3. The system of embodiment 1 wherein the elevation of the first reservoir is above the elevation of the second reservoir.

4. The system of embodiment 1 further comprising a third reservoir configured to store the liquid which has a higher density than water near the surface of the water body.

5. The system of embodiment 4 wherein said third reservoir is substantially at the same elevation as the second reservoir.

6. The system of embodiment 4 wherein the fluid which has a higher density than water is displaced from the second reservoir during storing of power is transferred to and stored in said third reservoir.

7. The system of embodiment 4 wherein the fluid which has a higher density than water is displaced from the second reservoir during storing of power is transferred to and stored in said third reservoir.

8. The system of embodiment 1 wherein said fluid which has a higher density than water comprises brine, or reverse osmosis discharge brine, or sodium chloride, or sea salt, or calcium chloride, or magnesium chloride, or potassium formate, or magnesium sulfate, or calcium bromide, or sodium bromide, or potassium acetate, or sodium formate, or calcium nitrate, or sodium nitrate, or sodium sulfite, or potassium sulfite, or sodium bisulfite, or potassium bisulfite, or magnesium sulfite, or magnesium bisulfite, or calcium bisulfite, or corn syrup, or glycerin, or propylene glycol, or ethylene glycol, or propylene carbonate, or any combination thereof.

9. The system of embodiment 1 wherein said fluid which has a higher density than water comprises a halogenated hydrocarbon, or a fluorocarbon, or an organic acid, or an inorganic acid, or carbon dioxide, or sulfur dioxide, or a nitrogen oxide, or any combination thereof.
10. The system of embodiment 1 wherein said fluid which has a lower density than water comprises a hydrocarbon.
11. The system of embodiment 1 wherein said fluid which has a lower density than water comprises air.
12. The system of embodiment 1 wherein the density of said fluid which has a higher density than water is greater than 1.02 kilograms per liter at 20°C.
13. The system of embodiment 1 wherein the density of said fluid which has a higher density than water is greater than 1.05 kilograms per liter at 20°C.
14. The system of embodiment 1 wherein the pressure inside the second reservoir and the pressure of the adjacent body of water differ by from about 0 bar to about 10 bar.
15. The system of embodiment 1 further comprising a pressure exchanger.
16. The system of embodiment 15 wherein said pressure exchanger is located near the second reservoir.
17. The system of embodiment 15 wherein during storing of power, the pressure exchanger extracts pressure from the liquid which has a lower density than water and transfers the extracted pressure to the liquid which has a higher density than water.
18. The system of embodiment 15 wherein during storing of power, the pressure exchanger extracts pressure from the liquid which has a higher density than water and transfers the extracted pressure to the liquid which has a lower density than water.
19. The system of embodiment 17 wherein said pressure extraction occurs (1) while the liquid which has a lower density than water is being transferred to the second reservoir or (2) prior to transfer or (3) both (1) and (2).
20. The system of embodiment 18 wherein said pressure extraction occurs (1) while the liquid which has a higher density than water is being transferred to the second reservoir or (2) prior to transfer or (3) both (1) and (2).
21. The system of embodiment 17 wherein the pressure exchanger extracts pressure less than or equal to the pressure of the liquid which has a lower density than water near the second reservoir minus the hydrostatic pressure of the body of water at the elevation of the second reservoir.

22. The system of embodiment 18 wherein the pressure exchanger extracts pressure less than or equal to the pressure of the liquid which has a higher density than water near the second reservoir minus the hydrostatic pressure of the body of water at the elevation of the second reservoir.
23. The system of embodiment 15 wherein the pressure exchanger enables the use of a liquid with a higher density than the density of the liquid in the body of water while enabling the second reservoir to be at pressure equilibrium with the body of water at the same elevation as the second reservoir.
24. The system of embodiment 15 wherein the pressure exchanger comprises a hydraulic pressure exchanger.
25. The system of embodiment 15 wherein the pressure exchanger adjusts pressure extraction to ensure the pressure of fluid inside the second reservoir differs from the hydrostatic pressure of the body of water at the same elevation as the second reservoir by less than a tolerance pressure.
26. The system of embodiment 25 wherein the second reservoir contains an internal pressure sensor and an external pressure sensor;
wherein the internal pressure sensor measures the pressure of fluids inside the second reservoir; and
wherein the external pressure sensor measures the pressure of the body of water adjacent to the second reservoir; and
wherein the internal pressure sensor and the external pressure sensor are configured to communicate with the pressure exchanger.
27. The system of embodiment 25 wherein said tolerance pressure is less than about 10 atm.
28. The system of embodiment 15 wherein the pressure exchanger is a hydraulic pressure exchanger.
29. The system of embodiment 15 wherein the pressure exchanger is a pump, or turbine, or rotary turbine, or any combination thereof.
30. A process for storing and generating power comprising:
[0637] operatively connecting a pump, a generator, a first storage reservoir near the surface of a body of water, and a second storage reservoir located below the surface of the body of water; wherein the first storage reservoir is configured to store a fluid which has a lower density than water and wherein the second storage reservoir is configured to store a fluid which has a higher density than water;

[0638] storing power by displacing the fluid which has a higher density than water in the second storage reservoir by pumping the fluid which has a lower density than water in the first storage reservoir to the second storage reservoir; and

[0639] generating or discharging power by allowing the fluid which has a lower density than water in the second storage reservoir to return to the first storage reservoir;

[0640] wherein the fluid which has a higher density than water is in liquid form.

[0641] Wherein the high density liquid possesses a density greater than 1.035 g/mL

[0642] subsea power recovery or power recovery near the lower elevation reservoir to enable the use of a liquid with a higher density than ocean water while enabling the subsea reservoir to be at pressure equilibrium with the ocean water

[0643] Pressure equalizer and pressure equalizer tank, wherein fluid is added to the lower elevation reservoir if the pressure in the reservoir is less than the surrounding pressure and fluid is removed from the lower elevation reservoir if the pressure in the reservoir is greater than the surrounding pressure

[0644] Refrigeration or cooling or thermal management of low density liquid

[0645] Wherein low density liquid and high density liquid are stored in the same higher elevation tank

[0646] Wherein low density liquid and high density liquid are stored in different higher elevation tanks

[0647] Wherein the higher elevation reservoir is pressurized

[0648] Wherein the higher elevation reservoir is maintained below a certain pressure by maintaining below a certain temperature using thermal management

[0649] **Notes**

- **Note:** A pressure equalizer may be connected to or attached to or both a tank, or a pipe, or a valve, or a fitting, or a connector, or a combination thereof.
- **Note:** A power exchanger, or pressure exchanger, or energy recovery system, or PX pressure exchanger may comprise a similar system to systems employed for hydraulic power or energy recovery in reverse osmosis systems in the art. The terms ‘Power exchanger’, or ‘pressure exchanger’, or ‘energy recovery system’, or ‘PX pressure exchanger’ may be used interchangeably.
- **Note:** A high density liquid may include, but is not limited to, liquids with a density greater than or equal to the density of water.

- **Note:** Aqueous salt solutions may be employed under conditions to minimize or eliminate corrosion. For example, corrosion may be inhibited by sacrificial anodes. For example, some embodiments may comprise ‘closed systems’ which may enable adjustments to composition and / or the creation of environments to minimize corrosion. For example, a salt solution may be deoxygenated by oxygen scavengers, such as sulfites, or nitrites, or bisulfites, or organic acids, or antioxidants. For example, a salt solution may be deoxygenated by a non-diatomic oxygen gas, such as nitrogen. For example, a salt solution may be deoxygenated by reaction of dissolved oxygen with a fuel, such as hydrogen or methane. For example, a brine solution may be deoxygenated by a catalytic deoxygenation process. For example, a brine solution may be deoxygenated by a catalytic deoxygenation process involve dissolving hydrogen gas than reacting dissolved oxygen with the dissolved hydrogen in the presence of a catalyst, such as a palladium catalyst, to form water and eliminate at least a portion of the dissolved diatomic oxygen. Corrosion may be significantly inhibited or practically eliminated deoxygenating the salt solution employed in a closed system. Dissolved oxygen levels may be monitored and dissolved oxygen may be removed if the concentration of dissolved oxygen increases or increases beyond a design threshold or defined concentration.
- **Note:** In some embodiments, a higher density liquid may comprise a halogenated hydrocarbon or a fluorocarbon liquid.
- **Note:** Some embodiments of the present invention may involve a high density liquid with a density greater than ocean water and a higher elevation high density liquid reservoir with an elevation greater than the elevation of the surface of the ocean.
- **Note:** In some embodiments, both the low density liquid and high density liquid higher elevation reservoirs may be at about the same or at a similar elevation and / or may be both at an elevation greater than ocean surface. In some embodiments, the low density liquid and high density liquid higher elevation reservoirs may be at different elevations and / or may be both at an elevation greater than ocean surface. In some embodiments, the low density liquid and high density liquid higher elevation reservoirs may be at different elevations and / or the low density liquid higher elevation reservoir may be located at a higher elevation than the elevation of the high density liquid higher elevation reservoir. In some embodiments, the low density liquid and high density liquid higher elevation reservoirs may be at different elevations and / or the low density liquid higher elevation

reservoir may be located at a lower elevation than the elevation of the high density liquid higher elevation reservoir.

- **Note:** The concentration of a reagent in a brine may be adjusted. For example, the concentration of a reagent in a solution, such as a brine, may be adjusted if the temperature of the brine changes, or the solubility of the brine changes, or the viscosity of the brine changes, or a combination thereof.
- **Note:** Some high density liquids are more desirable than others and some high density liquids may be mixed with others. Example high density liquids with a density greater than water, or a density greater than ocean water, or both may include, but are not limited to, one or more or a combination of the following: water, or brine, or sodium chloride, or sea salt, or reverse osmosis brine, or concentrate, or retentate, or calcium chloride, or magnesium chloride, or potassium formate, or magnesium sulfate, or calcium bromide, or sodium bromide, or potassium acetate, or sodium formate, or calcium nitrate, or sodium nitrate, or magnesium chloride, or magnesium sulfite, or sodium sulfite, or sodium bisulfite, or potassium sulfite, or potassium bisulfite, or calcium bisulfite, or magnesium bisulfite, or sulfur dioxide, or calcium nitrite, or magnesium nitrite, or sodium nitrite, or potassium nitrite, or carboxylic acids, or salts of carboxylic acids, or acetic acid, or citric acid, or corn syrup, or corn syrup, or glycerin, or organic reagents with a density greater than water, or sugar, or sucrose, or dextrose, or sugar alcohols, or polyols, or ethylene glycol, or propylene glycol, or propylene carbonate, or insoluble organic reagents, or soluble organic reagents, or fluorocarbons, or halogenated hydrocarbons, or perfluorocarbons, or inorganic compounds, or liquid sulfur dioxide, or liquid carbon dioxide, or dinitrogen tetroxide, or dinitrogen pentoxide, or sulfur trioxide, or nitrous oxide, or organic acids, or inorganic acids, or molten sulfur, or liquid sulfur, or refrigerants, or bromine, or chloride, or iodine, or halogen, or formic acid, or chlorine dioxide, or hydrogen peroxide, or organic acids, or inorganic acids, or organic bases, or inorganic bases, or 1,2-Dibromoethane, or cis-1,2-Dibromoethene, or trans-1,2-Dibromoethene, or Dibromomethane, or Bromal, or Bromoform, or 1,1,2,2-Tetrabromoethane (Muthmanns solution), or Sodium polytungstate, or Bromine, or Thoulets solution, or Diiodomethane, or Indiumiodide, or Bariummercuriodide, or Thallium formate + Thallium malonate (Clerici solution), or Galinstan (Gallium/Indium/Tin alloy), or Mercury, or Cesium Formate, or lead, or mercury, or gallium, or liquid metal, or nanoparticles, or dispersed nanoparticles, or suspended nanoparticles, or iron, or gold, or nickel, or tungsten, or sulfur

dioxide + carbon dioxide, or refrigerant mixtures, or sulfurous acid, or nitrous acid, or an ionic compound, or an organic compound, or a chemical comprising carbon, or an element, or a chemical with a density greater than the density of a low density liquid, or a chemical with a density greater than the density of water, or a chemical

- **Note:** Pressure exchangers or power exchangers may extract power or pressure from a fluid, such as a liquid, or a gas, or a supercritical fluid, or liquid-solid mixtures, or gas-liquid mixtures, or a combination thereof. Pressure exchangers or power exchangers may extract power or pressure from a fluid transfer said extracted power or pressure to another fluid. Example pressure exchangers or power exchangers may include, but are not limited to, one or more or a combination of the following: rotary pressure exchangers, or hydraulic pressure exchangers, or pneumatic pressure exchangers, or pressure exchangers employed in the art for reverse osmosis systems, or hydraulic turbine, or hydraulic turbocharger, or hydraulic impeller, or mechanical exchanger, or hydraulic exchanger, or electrical exchanger, or displacement exchanger, or turbine nozzle, or diffuser, or booster pump, or Ultra PX, or ultra high pressure hydraulic energy recovery, or energy recovery device, or high efficiency pressure exchanger, mixed fluid pressure exchangers, pressure exchangers known in the art for desalination systems, pressure exchangers known in the art for refining and petrochemical systems
- **Note:** Mechanical pressure exchangers can be significantly more energy efficient than, for example, generators. For example, pressure exchangers employed in the art in reverse osmosis have shown energy efficiencies or pressure exchanging efficiency of up to 98% or 99%.
- **Note:** Some embodiments may involve one or more pressure sensors. Internal pressure sensors may comprise pressure sensors which measure the pressure of a fluid inside at least a portion of the energy storage process. External pressure sensors may comprise pressure sensors which measure the pressure of a fluid or material outside or external to at least a portion of the energy storage system or process. It may be desirable for an external pressure sensor to measure the pressure of an external fluid or material to determine the pressure of said fluid or material acting on at least one surface of the energy storage system or process.
- **Note:** The elevation difference between the first reservoir and the second reservoir is less than, or greater than, or equal to, one or more or a combination of the following: 50 meters, or 100 meters, or 150 meters, or 200 meters, or 250 meters, or 300 meters, or 350 meters, or 400 meters, or 450 meters, or 500 meters, or 550 meters, or 600 meters, or 650 meters,

or 700 meters, or 750 meters, or 800 meters, or 850 meters, or 900 meters, or 950 meters, or 1,000 meters, or 1,050 meters, or 1,100 meters, or 1,150 meters, or 1,200 meters, or 1,250 meters, or 1,300 meters, 1,350 meters, or 1,400 meters, or 1,450 meters, or 1,500 meters, or 1,550 meters, or 1,600 meters, or 1,650 meters, or 1,700 meters, or 1,750 meters, or 1,800 meters, or 1,850 meters, or 1,900 meters, or 1,950 meters, or 2,000 meters, or 2,050 meters, or 2,100 meters, or 2,150 meters, or 2,200 meters, or 2,250 meters, or 2,300 meters, or 2,350 meters, or 2,400 meters, or 2,450 meters, or 2,500 meters, or 2,550 meters, or 2,600 meters, or 2,650 meters, or 2,700 meters, or 2,750 meters, or 2,800 meters, or 2,850 meters, or 2,900 meters, or 2,950 meters, or 3,000 meters, or 3,100 meters, or 3,200 meters, or 3,300 meters, or 3,400 meters, or 3,500 meters, or 3,600 meters, or 3,700 meters, or 3,800 meters, or 3,900 meters, or 4,000 meters, or 4,100 meters, or 4,200 meters, or 4,300 meters, or 4,400 meters, or 4,500 meters, or 4,600 meters, or 4,700 meters, or 4,800 meters, or 4,900 meters, or 5,000 meters, or 5,500 meters, or 6,000 meters, or 6,500 meters, or 7,000 meters, or 7,500 meters, or 8,000 meters, or 8,500 meters, or 9,000 meters, or 9,500 meters, or 10,000 meters, or 10,500 meters, or 11,000 meters, or 11,500 meters, or 12,000 meters, or 12,500 meters, or 13,000 meters, or 13,500 meters

- **Note:** Elevation difference between the third reservoir and the second reservoir is less than, or greater than, or equal to, one or more or a combination of the following: 50 meters, or 100 meters, or 150 meters, or 200 meters, or 250 meters, or 300 meters, or 350 meters, or 400 meters, or 450 meters, or 500 meters, or 550 meters, or 600 meters, or 650 meters, or 700 meters, or 750 meters, or 800 meters, or 850 meters, or 900 meters, or 950 meters, or 1,000 meters, or 1,050 meters, or 1,100 meters, or 1,150 meters, or 1,200 meters, or 1,250 meters, or 1,300 meters, 1,350 meters, or 1,400 meters, or 1,450 meters, or 1,500 meters, or 1,550 meters, or 1,600 meters, or 1,650 meters, or 1,700 meters, or 1,750 meters, or 1,800 meters, or 1,850 meters, or 1,900 meters, or 1,950 meters, or 2,000 meters, or 2,050 meters, or 2,100 meters, or 2,150 meters, or 2,200 meters, or 2,250 meters, or 2,300 meters, or 2,350 meters, or 2,400 meters, or 2,450 meters, or 2,500 meters, or 2,550 meters, or 2,600 meters, or 2,650 meters, or 2,700 meters, or 2,750 meters, or 2,800 meters, or 2,850 meters, or 2,900 meters, or 2,950 meters, or 3,000 meters, or 3,100 meters, or 3,200 meters, or 3,300 meters, or 3,400 meters, or 3,500 meters, or 3,600 meters, or 3,700 meters, or 3,800 meters, or 3,900 meters, or 4,000 meters, or 4,100 meters, or 4,200 meters, or 4,300 meters, or 4,400 meters, or 4,500 meters, or 4,600 meters, or 4,700 meters, or 4,800 meters, or 4,900 meters, or 5,000 meters, or 5,500 meters, or 6,000 meters, or 6,500 meters,

or 7,000 meters, or 7,500 meters, or 8,000 meters, or 8,500 meters, or 9,000 meters, or 9,500 meters, or 10,000 meters, or 10,500 meters, or 11,000 meters, or 11,500 meters, or 12,000 meters, or 12,500 meters, or 13,000 meters, or 13,500 meters

- **Note:** The elevation difference between two reservoirs is less than, or greater than, or equal to, one or more or a combination of the following: 50 meters, or 100 meters, or 150 meters, or 200 meters, or 250 meters, or 300 meters, or 350 meters, or 400 meters, or 450 meters, or 500 meters, or 550 meters, or 600 meters, or 650 meters, or 700 meters, or 750 meters, or 800 meters, or 850 meters, or 900 meters, or 950 meters, or 1,000 meters, or 1,050 meters, or 1,100 meters, or 1,150 meters, or 1,200 meters, or 1,250 meters, or 1,300 meters, or 1,350 meters, or 1,400 meters, or 1,450 meters, or 1,500 meters, or 1,550 meters, or 1,600 meters, or 1,650 meters, or 1,700 meters, or 1,750 meters, or 1,800 meters, or 1,850 meters, or 1,900 meters, or 1,950 meters, or 2,000 meters, or 2,050 meters, or 2,100 meters, or 2,150 meters, or 2,200 meters, or 2,250 meters, or 2,300 meters, or 2,350 meters, or 2,400 meters, or 2,450 meters, or 2,500 meters, or 2,550 meters, or 2,600 meters, or 2,650 meters, or 2,700 meters, or 2,750 meters, or 2,800 meters, or 2,850 meters, or 2,900 meters, or 2,950 meters, or 3,000 meters, or 3,100 meters, or 3,200 meters, or 3,300 meters, or 3,400 meters, or 3,500 meters, or 3,600 meters, or 3,700 meters, or 3,800 meters, or 3,900 meters, or 4,000 meters, or 4,100 meters, or 4,200 meters, or 4,300 meters, or 4,400 meters, or 4,500 meters, or 4,600 meters, or 4,700 meters, or 4,800 meters, or 4,900 meters, or 5,000 meters, or 5,500 meters, or 6,000 meters, or 6,500 meters, or 7,000 meters, or 7,500 meters, or 8,000 meters, or 8,500 meters, or 9,000 meters, or 9,500 meters, or 10,000 meters, or 10,500 meters, or 11,000 meters, or 11,500 meters, or 12,000 meters, or 12,500 meters, or 13,000 meters, or 13,500 meters
- **Note:** The viscosity of a liquid may be less than, or greater than, or equal to, including, but not limited to, one or more or a combination of the following: 0.1cP, or 0.5cP, or 1cP, or 1.5cP, or 2cP, or 2.5cP, or 3cP, or 3.5cP, or 4cP, or 4.5cP, or 5cP, or 5.5cP, or 6cP, or 6.5cP, or 7cP, or 7.5cP, or 8cP, or 8.5cP, or 9cP, or 9.5cP, or 10cP, or 11cP, or 12cP, or 13cP, or 14cP, or 15cP, or 16cP, or 17cP, or 18cP, or 19cP, or 20cP, or 21cP, or 22cP, or 23cP, or 24cP, or 25cP, or 26cP, or 27cP, or 28cP, or 29cP, or 30cP, or 31cP, or 32cP, or 33cP, or 34cP, or 35cP, or 36cP, or 37cP, or 38cP, or 39cP, or 40cP, or 41cP, or 42cP, or 43cP, or 44cP, or 45cP, or 46cP, or 47cP, or 48cP, or 49cP, or 50cP, or 55cP, or 60cP, or 65cP, or 70cP, or 75cP, or 80cP, or 85cP, or 90cP, or 95cP, or 100cP, or 105cP, or 110cP, or 115cP, or 120cP, or 125cP, or 130cP, or 135cP, or 140cP, or 145cP, or 150cP, or 155cP,

or 160cP, or 165cP, or 170cP, or 175cP, or 180cP, or 185cP, or 190cP, or 195cP, or 200cP, or 205cP, or 210cP, or 215cP, or 220cP, or 225cP, or 230cP, or 235cP, or 240cP, or 245cP, or 250cP, or 255cP, or 260cP, or 265cP, or 270cP, or 275cP, or 280cP, or 285cP, or 290cP, or 295cP, or 300cP, or 305cP, or 310cP, or 315cP, or 320cP, or 325cP, or 330cP, or 335cP, or 340cP, or 345cP, or 350cP, or 355cP, or 360cP, or 365cP, or 370cP, or 375cP, or 380cP, or 385cP, or 390cP, or 395cP, or 400cP, or 405cP, or 410cP, or 415cP, or 420cP, or 425cP, or 430cP, or 435cP, or 440cP, or 445cP, or 450cP, or 455cP, or 460cP, or 465cP, or 470cP, or 475cP, or 480cP, or 485cP, or 490cP, or 495cP, or 500cP, or 550cP, or 600cP, or 650cP, or 700cP, or 750cP, or 800cP, or 850cP, or 900cP, or 950cP, or 1,000cP, or 1,250cP, or 1,500cP, or 1,750cP, or 2,000cP, or 2,250cP, or 2,500cP, or 2,750cP, or 3,000cP, or 3,250cP, or 3,500cP, or 3,750cP, or 4,000cP, or 4,250cP, or 4,500cP, or 4,750cP, or 5,000cP, or 5,250cP, or 5,500cP, or 5,750cP, or 6,000cP, or 6,250cP, or 6,500cP, or 6,750cP, or 7,000cP, or 7,250cP, or 7,500cP, or 7,750cP, or 8,000cP, or 8,250cP, or 8,500cP, or 8,750cP, or 9,000cP, or 9,250cP, or 9,500cP, or 9,750cP or 10,000cP

- **Note:** The temperature of the high density liquid, or the low density liquid, or the thermal storage medium, or any combination thereof may be less than, or greater than, or equal to one or more or a combination of the following: -100°C, or -90°C, or -80°C, or -70°C, or -60°C, or -50°C, or -45°C, or -40°C, or -35°C, or -30°C, or -25°C, or -20°C, or -19°C, or -18°C, or -17°C, or -16°C, or -15°C, or -15°C, or -14°C, or -13°C, -12°C, or -11°C, or -10°C, or -9°C, or -8°C, or -7°C, or -6°C, or -5°C, or -4°C, or -3°C or -2°C, or -1°C, or 0°C, or 1°C, or 2°C, or 3°C, or 4°C, or 5°C, or 6°C, or 7°C, or 8°C, or 9°C, or 10°C, or 11°C, or 12°C, or 13°C, or 14°C, or 15°C, or 16°C, or 17°C, or 18°C, or 19°C, or 20°C, or 21°C, or 22°C, or 23°C, or 24°C, or 25°C, or 26°C, or 27°C, or 28°C, or 29°C, or 30°C, or 31°C, or 32°C, or 33°C, or 34°C, or 35°C, or 36°C, or 37°C, or 38°C, or 39°C, or 40°C, or 41°C, or 42°C, or 43°C, or 44°C, or 45°C, or 46°C, or 47°C, or 48°C, or 49°C, or 50°C, or 51°C, or 52°C, or 53°C, or 54°C, or 55°C, or 56°C, or 57°C, or 58°C, or 59°C, or 60°C, or 61°C, or 62°C, or 63°C, or 64°C, or 65°C, or 66°C, or 67°C, or 68°C, or 69°C, or 70°C, or 71°C, or 72°C, or 73°C, or 74°C, or 75°C, or 76°C, or 77°C, or 78°C, or 79°C, or 80°C, or 81°C, or 82°C, or 83°C, or 84°C, or 85°C, or 86°C, or 87°C, or 88, or 89°C, or 90°C, or 91°C, or 92°C, or 93°C, or 94°C, or 95°C, or 96°C, or 97°C, or 98°C, or 99°C, or 100°C, or 110°C, or 120°C, or 130°C, or 140°C, or 150°C, or 160°C, or 170°C, or 180°C, or 190°C, or 200°C, or 210°C, or 220°C, or 230°C, or 240°C, or 250°C, or 260°C, or 270°C, or 280°C, or 290°C, or 300°C, or 310°C, or 320°C, or 330°C, or 340°C, or 350°C, or 360°C, or 370°C, or 380°C, or 390°C,

or 400°C, or 410°C, or 420°C, or 430°C, or 440°C, or 450°C, or 460°C, or 470°C, or 480°C, or 490°C, or 500°C, or 550°C, or 600°C, or 700°C, or 800°C, or 900°C, or 1000°C

- **Note:** The weight percent concentration of the high density liquid in the low density liquid may be less than, or greater than, or equal to one or more or a combination of the following: 0.0001%, or 0.5%, or 1%, or 1.5%, or 2%, or 2.5%, or 3%, or 3.5%, or 4%, or 4.5%, or 5%, or 5.5%, or 6%, or 6.5%, or 7%, or 7.5%, or 8%, or 8.5%, or 9%, or 9.5%, or 10%, or 10.5%, or 11%, or 11.5%, or 12%, or 12.5%, or 13%, or 13.5%, or 14%, or 14.5%, or 15%, or 15.5%, or 16%, or 16.5%, or 17%, or 17.5%, or 18%, or 18.5%, or 19%, or 19.5%, or 20%, or 20.5%, or 21%, or 21.5%, or 22%, or 22.5%, or 23%, or 23.5%, or 24%, or 24.5%, or 25%, or 25.5%, or 26%, or 26.5%, or 27%, or 27.5%, or 28%, or 28.5%, or 29%, or 29.5%, or 30%, or 30.5%, or 31%, or 31.5%, or 32%, or 32.5%, or 33%, or 33.5%, or 34%, or 34.5%, or 35%, or 35.5%, or 36%, or 36.5%, or 37%, or 37.5%, or 38%, or 38.5%, or 39%, or 39.5%, or 40%, or 40.5%, or 41%, or 41.5%, or 42%, or 42.5%, or 43%, or 43.5%, or 44%, or 44.5%, or 45%, or 45.5%, or 46%, or 46.5%, or 47%, or 47.5%, or 48%, or 48.5%, or 49%, or 49.5%, or 50%, or 50.5%, or 51%, or 51.5%, or 52%, or 52.5%, or 53%, or 53.5%, or 54%, or 54.5%, or 55%, or 55.5%, or 56%, or 56.5%, or 57%, or 57.5%, or 58%, or 58.5%, or 59%, or 59.5%, or 60%, or 60.5%, or 61%, or 61.5%, or 62%, or 62.5%, or 63%, or 63.5%, or 64%, or 64.5%, or 65%, or 65.5%, or 66%, or 66.5%, or 67%, or 67.5%, or 68%, or 68.5%, or 69%, or 69.5%, or 70%, or 70.5%, or 71%, or 71.5%, or 72%, or 72.5%, or 73%, or 73.5%, or 74%, or 74.5%, or 75%, or 75.5%, or 76%, or 76.5%, or 77%, or 77.5%, or 78%, or 78.5%, or 79%, or 79.5%, or 80%, or 80.5%, or 81%, or 81.5%, or 82%, or 82.5%, or 83%, or 83.5%, or 84%, or 84.5%, or 85%, or 85.5%, or 86%, or 86.5%, or 87%, or 87.5%, or 88%, or 88.5%, or 89%, or 89.5%, or 90%, or 90.5%, or 91%, or 91.5%, or 92%, or 92.5%, or 93%, or 93.5%, or 94%, or 94.5%, or 95%, or 95.5%, or 96%, or 96.5%, or 97%, or 97.5%, or 98%, or 98.5%, or 99%, or 99.5%, or 99.999%
- **Note:** The weight percent concentration of low density liquid in the high density liquid may be less than, or greater than, or equal to one or more or a combination of the following: 0.0001%, or 0.5%, or 1%, or 1.5%, or 2%, or 2.5%, or 3%, or 3.5%, or 4%, or 4.5%, or 5%, or 5.5%, or 6%, or 6.5%, or 7%, or 7.5%, or 8%, or 8.5%, or 9%, or 9.5%, or 10%, or 10.5%, or 11%, or 11.5%, or 12%, or 12.5%, or 13%, or 13.5%, or 14%, or 14.5%, or 15%, or 15.5%, or 16%, or 16.5%, or 17%, or 17.5%, or 18%, or 18.5%, or 19%, or 19.5%, or 20%, or 20.5%, or 21%, or 21.5%, or 22%, or 22.5%, or 23%, or 23.5%, or 24%, or 24.5%,

or 25%, or 25.5%, or 26%, or 26.5%, or 27%, or 27.5%, or 28%, or 28.5%, or 29%, or 29.5%, or 30%, or 30.5%, or 31%, or 31.5%, or 32%, or 32.5%, or 33%, or 33.5%, or 34%, or 34.5%, or 35%, or 35.5%, or 36%, or 36.5%, or 37%, or 37.5%, or 38%, or 38.5%, or 39%, or 39.5%, or 40%, or 40.5%, or 41%, or 41.5%, or 42%, or 42.5%, or 43%, or 43.5%, or 44%, or 44.5%, or 45%, or 45.5%, or 46%, or 46.5%, or 47%, or 47.5%, or 48%, or 48.5%, or 49%, or 49.5%, or 50%, or 50.5%, or 51%, or 51.5%, or 52%, or 52.5%, or 53%, or 53.5%, or 54%, or 54.5%, or 55%, or 55.5%, or 56%, or 56.5%, or 57%, or 57.5%, or 58%, or 58.5%, or 59%, or 59.5%, or 60%, or 60.5%, or 61%, or 61.5%, or 62%, or 62.5%, or 63%, or 63.5%, or 64%, or 64.5%, or 65%, or 65.5%, or 66%, or 66.5%, or 67%, or 67.5%, or 68%, or 68.5%, or 69%, or 69.5%, or 70%, or 70.5%, or 71%, or 71.5%, or 72%, or 72.5%, or 73%, or 73.5%, or 74%, or 74.5%, or 75%, or 75.5%, or 76%, or 76.5%, or 77%, or 77.5%, or 78%, or 78.5%, or 79%, or 79.5%, or 80%, or 80.5%, or 81%, or 81.5%, or 82%, or 82.5%, or 83%, or 83.5%, or 84%, or 84.5%, or 85%, or 85.5%, or 86%, or 86.5%, or 87%, or 87.5%, or 88%, or 88.5%, or 89%, or 89.5%, or 90%, or 90.5%, or 91%, or 91.5%, or 92%, or 92.5%, or 93%, or 93.5%, or 94%, or 94.5%, or 95%, or 95.5%, or 96%, or 96.5%, or 97%, or 97.5%, or 98%, or 98.5%, or 99%, or 99.5%, or 99.999%

- **Note:** The weight percent concentration of water in the high density liquid may be less than, or greater than, or equal to one or more or a combination of the following: 0.0001%, or 0.5%, or 1%, or 1.5%, or 2%, or 2.5%, or 3%, or 3.5%, or 4%, or 4.5%, or 5%, or 5.5%, or 6%, or 6.5%, or 7%, or 7.5%, or 8%, or 8.5%, or 9%, or 9.5%, or 10%, or 10.5%, or 11%, or 11.5%, or 12%, or 12.5%, or 13%, or 13.5%, or 14%, or 14.5%, or 15%, or 15.5%, or 16%, or 16.5%, or 17%, or 17.5%, or 18%, or 18.5%, or 19%, or 19.5%, or 20%, or 20.5%, or 21%, or 21.5%, or 22%, or 22.5%, or 23%, or 23.5%, or 24%, or 24.5%, or 25%, or 25.5%, or 26%, or 26.5%, or 27%, or 27.5%, or 28%, or 28.5%, or 29%, or 29.5%, or 30%, or 30.5%, or 31%, or 31.5%, or 32%, or 32.5%, or 33%, or 33.5%, or 34%, or 34.5%, or 35%, or 35.5%, or 36%, or 36.5%, or 37%, or 37.5%, or 38%, or 38.5%, or 39%, or 39.5%, or 40%, or 40.5%, or 41%, or 41.5%, or 42%, or 42.5%, or 43%, or 43.5%, or 44%, or 44.5%, or 45%, or 45.5%, or 46%, or 46.5%, or 47%, or 47.5%, or 48%, or 48.5%, or 49%, or 49.5%, or 50%, or 50.5%, or 51%, or 51.5%, or 52%, or 52.5%, or 53%, or 53.5%, or 54%, or 54.5%, or 55%, or 55.5%, or 56%, or 56.5%, or 57%, or 57.5%, or 58%, or 58.5%, or 59%, or 59.5%, or 60%, or 60.5%, or 61%, or 61.5%, or 62%, or 62.5%, or 63%, or 63.5%, or 64%, or 64.5%, or 65%, or 65.5%, or 66%, or 66.5%, or 67%, or 67.5%, or 68%,

or 68.5%, or 69%, or 69.5%, or 70%, or 70.5%, or 71%, or 71.5%, or 72%, or 72.5%, or 73%, or 73.5%, or 74%, or 74.5%, or 75%, or 75.5%, or 76%, or 76.5%, or 77%, or 77.5%, or 78%, or 78.5%, or 79%, or 79.5%, or 80%, or 80.5%, or 81%, or 81.5%, or 82%, or 82.5%, or 83%, or 83.5%, or 84%, or 84.5%, or 85%, or 85.5%, or 86%, or 86.5%, or 87%, or 87.5%, or 88%, or 88.5%, or 89%, or 89.5%, or 90%, or 90.5%, or 91%, or 91.5%, or 92%, or 92.5%, or 93%, or 93.5%, or 94%, or 94.5%, or 95%, or 95.5%, or 96%, or 96.5%, or 97%, or 97.5%, or 98%, or 98.5%, or 99%, or 99.5%, or 99.999%

- **Note:** The weight percent concentration of water in the low density liquid may be less than, or greater than, or equal to one or more or a combination of the following: 0.0001%, or 0.5%, or 1%, or 1.5%, or 2%, or 2.5%, or 3%, or 3.5%, or 4%, or 4.5%, or 5%, or 5.5%, or 6%, or 6.5%, or 7%, or 7.5%, or 8%, or 8.5%, or 9%, or 9.5%, or 10%, or 10.5%, or 11%, or 11.5%, or 12%, or 12.5%, or 13%, or 13.5%, or 14%, or 14.5%, or 15%, or 15.5%, or 16%, or 16.5%, or 17%, or 17.5%, or 18%, or 18.5%, or 19%, or 19.5%, or 20%, or 20.5%, or 21%, or 21.5%, or 22%, or 22.5%, or 23%, or 23.5%, or 24%, or 24.5%, or 25%, or 25.5%, or 26%, or 26.5%, or 27%, or 27.5%, or 28%, or 28.5%, or 29%, or 29.5%, or 30%, or 30.5%, or 31%, or 31.5%, or 32%, or 32.5%, or 33%, or 33.5%, or 34%, or 34.5%, or 35%, or 35.5%, or 36%, or 36.5%, or 37%, or 37.5%, or 38%, or 38.5%, or 39%, or 39.5%, or 40%, or 40.5%, or 41%, or 41.5%, or 42%, or 42.5%, or 43%, or 43.5%, or 44%, or 44.5%, or 45%, or 45.5%, or 46%, or 46.5%, or 47%, or 47.5%, or 48%, or 48.5%, or 49%, or 49.5%, or 50%, or 50.5%, or 51%, or 51.5%, or 52%, or 52.5%, or 53%, or 53.5%, or 54%, or 54.5%, or 55%, or 55.5%, or 56%, or 56.5%, or 57%, or 57.5%, or 58%, or 58.5%, or 59%, or 59.5%, or 60%, or 60.5%, or 61%, or 61.5%, or 62%, or 62.5%, or 63%, or 63.5%, or 64%, or 64.5%, or 65%, or 65.5%, or 66%, or 66.5%, or 67%, or 67.5%, or 68%, or 68.5%, or 69%, or 69.5%, or 70%, or 70.5%, or 71%, or 71.5%, or 72%, or 72.5%, or 73%, or 73.5%, or 74%, or 74.5%, or 75%, or 75.5%, or 76%, or 76.5%, or 77%, or 77.5%, or 78%, or 78.5%, or 79%, or 79.5%, or 80%, or 80.5%, or 81%, or 81.5%, or 82%, or 82.5%, or 83%, or 83.5%, or 84%, or 84.5%, or 85%, or 85.5%, or 86%, or 86.5%, or 87%, or 87.5%, or 88%, or 88.5%, or 89%, or 89.5%, or 90%, or 90.5%, or 91%, or 91.5%, or 92%, or 92.5%, or 93%, or 93.5%, or 94%, or 94.5%, or 95%, or 95.5%, or 96%, or 96.5%, or 97%, or 97.5%, or 98%, or 98.5%, or 99%, or 99.5%, or 99.999%
- **Note:** In some embodiments, to ensure maximum energy density and minimize liquid volumes required, the elevation difference between the first and second reservoir is greater than or equal to one or more or a combination of the following: 50 meters, or 100 meters,

or 150 meters, or 200 meters, or 250 meters, or 500 meters, or 750 meters, or 1,000 meters, or 1,250 meters, or 1,500 meters

- **Note:** Energy storage round-trip energy efficiency may be greater than or equal to one or more or a combination of the following: 0.0001%, or 0.5%, or 1%, or 1.5%, or 2%, or 2.5%, or 3%, or 3.5%, or 4%, or 4.5%, or 5%, or 5.5%, or 6%, or 6.5%, or 7%, or 7.5%, or 8%, or 8.5%, or 9%, or 9.5%, or 10%, or 10.5%, or 11%, or 11.5%, or 12%, or 12.5%, or 13%, or 13.5%, or 14%, or 14.5%, or 15%, or 15.5%, or 16%, or 16.5%, or 17%, or 17.5%, or 18%, or 18.5%, or 19%, or 19.5%, or 20%, or 20.5%, or 21%, or 21.5%, or 22%, or 22.5%, or 23%, or 23.5%, or 24%, or 24.5%, or 25%, or 25.5%, or 26%, or 26.5%, or 27%, or 27.5%, or 28%, or 28.5%, or 29%, or 29.5%, or 30%, or 30.5%, or 31%, or 31.5%, or 32%, or 32.5%, or 33%, or 33.5%, or 34%, or 34.5%, or 35%, or 35.5%, or 36%, or 36.5%, or 37%, or 37.5%, or 38%, or 38.5%, or 39%, or 39.5%, or 40%, or 40.5%, or 41%, or 41.5%, or 42%, or 42.5%, or 43%, or 43.5%, or 44%, or 44.5%, or 45%, or 45.5%, or 46%, or 46.5%, or 47%, or 47.5%, or 48%, or 48.5%, or 49%, or 49.5%, or 50%, or 50.5%, or 51%, or 51.5%, or 52%, or 52.5%, or 53%, or 53.5%, or 54%, or 54.5%, or 55%, or 55.5%, or 56%, or 56.5%, or 57%, or 57.5%, or 58%, or 58.5%, or 59%, or 59.5%, or 60%, or 60.5%, or 61%, or 61.5%, or 62%, or 62.5%, or 63%, or 63.5%, or 64%, or 64.5%, or 65%, or 65.5%, or 66%, or 66.5%, or 67%, or 67.5%, or 68%, or 68.5%, or 69%, or 69.5%, or 70%, or 70.5%, or 71%, or 71.5%, or 72%, or 72.5%, or 73%, or 73.5%, or 74%, or 74.5%, or 75%, or 75.5%, or 76%, or 76.5%, or 77%, or 77.5%, or 78%, or 78.5%, or 79%, or 79.5%, or 80%, or 80.5%, or 81%, or 81.5%, or 82%, or 82.5%, or 83%, or 83.5%, or 84%, or 84.5%, or 85%, or 85.5%, or 86%, or 86.5%, or 87%, or 87.5%, or 88%, or 88.5%, or 89%, or 89.5%, or 90%, or 90.5%, or 91%, or 91.5%, or 92%, or 92.5%, or 93%, or 93.5%, or 94%, or 94.5%, or 95%, or 95.5%, or 96%, or 96.5%, or 97%, or 97.5%, or 98%, or 98.5%, or 99%, or 99.5%, or 99.999%
- **Note:** The density of a liquid may be less than or equal to or greater than or equal to one or more or a combination of the following: 0.5g/mL, or 0.51g/mL, or 0.52g/mL, or 0.53g/mL, or 0.54g/mL, or 0.55g/mL, or 0.56g/mL, or 0.57g/mL, or 0.58g/mL, or 0.59g/mL, or 0.6g/mL, or 0.61g/mL, or 0.62g/mL, or 0.63g/mL, or 0.64g/mL, or 0.65g/mL, or 0.66g/mL, or 0.67g/mL, or 0.68g/mL, or 0.69g/mL, or 0.70 g/mL, or 0.71g/mL, or 0.72g/mL, or 0.73g/mL, or 0.74g/mL, or 0.75g/mL, or 0.76g/mL, or 0.77g/mL, or 0.78g/mL, or 0.79g/mL, or 0.8g/mL, or 0.805g/mL, or 0.81g/mL, or 0.815g/mL, or 0.82g/mL, or 0.825g/mL, or 0.83g/mL, or 0.835g/mL, or 0.84g/mL, or 0.845g/mL, or

0.85g/mL, or 0.855g/mL, or 0.86g/mL, or 0.865g/mL, or 0.87g/mL, or 0.875g/mL, or 0.88g/mL, or 0.885g/mL, or 0.89g/mL, or 0.895g/mL, or 0.9g/mL, or 0.905g/mL, or 0.91g/mL, or .915g/mL, or 0.92g/mL, or 0.925g/mL, or 0.93g/mL, or 0.935g/mL, or 0.94g/mL, or 0.945g/mL, or 0.95g/mL, or 0.955g/mL, or 0.96g/mL, or 0.965g/mL, or 0.97g/mL, or 0.975g/mL, or 0.98g/mL, or 0.985g/mL, or 0.99g/mL, or 0.995g/mL, or 1g/mL, or 1.005g/mL, or 1.01g/mL, or 1.015g/mL, or 1.02g/mL, or 1.025g/mL, or 1.03g/mL, or 1.035g/mL, or 1.04g/mL, or 1.045g/mL, or 1.05g/mL, or 1.055g/mL, or 1.06g/mL, or 1.065g/mL, or 1.07g/mL, or 1.075g/mL, or 1.08g/mL, or 1.085g/mL, or 1.09g/mL, or 1.095g/mL, or 1.1g/mL, or 1.11g/mL, or 1.12g/mL, or 1.13g/mL, or 1.14g/mL, or 1.15g/mL, or 1.16g/mL, or 1.17g/mL, or 1.18g/mL, or 1.19g/mL, or 1.2g/mL, or 1.21g/mL, or 1.22g/mL, or 1.23g/mL, or 1.24g/mL, or 1.25g/mL, or 1.26g/mL, or 1.27g/mL, or 1.28g/mL, or 1.29g/mL, or 1.3g/mL, or 1.31g/mL, or 1.32g/mL, or 1.33g/mL, or 1.34g/mL, or 1.35g/mL, or 1.36g/mL, or 1.37g/mL, or 1.38g/mL, or 1.39g/mL, or 1.4g/mL, or 1.41g/mL, or 1.42g/mL, or 1.43g/mL, or 1.44g/mL, or 1.45g/mL, or 1.46g/mL, or 1.47g/mL, or 1.48g/mL, or 1.49g/mL, or 1.5g/mL

- **Note:** The density of a fluid may be less than or equal to or greater than or equal to one or more or a combination of the following: 0.5g/mL, or 0.51g/mL, or 0.52g/mL, or 0.53g/mL, or 0.54g/mL, or 0.55g/mL, or 0.56g/mL, or 0.57g/mL, or 0.58g/mL, or 0.59g/mL, or 0.6g/mL, or 0.61g/mL, or 0.62g/mL, or 0.63g/mL, or 0.64g/mL, or 0.65g/mL, or 0.66g/mL, or 0.67g/mL, or 0.68g/mL, or 0.69g/mL, or 0.70 g/mL, or 0.71g/mL, or 0.72g/mL, or 0.73g/mL, or 0.74g/mL, or 0.75g/mL, or 0.76g/mL, or 0.77g/mL, or 0.78g/mL, or 0.79g/mL, or 0.8g/mL, or 0.805g/mL, or 0.81g/mL, or 0.815g/mL, or 0.82g/mL, or 0.825g/mL, or 0.83g/mL, or 0.835g/mL, or 0.84g/mL, or 0.845g/mL, or 0.85g/mL, or 0.855g/mL, or 0.86g/mL, or 0.865g/mL, or 0.87g/mL, or 0.875g/mL, or 0.88g/mL, or 0.885g/mL, or 0.89g/mL, or 0.895g/mL, or 0.9g/mL, or 0.905g/mL, or 0.91g/mL, or .915g/mL, or 0.92g/mL, or 0.925g/mL, or 0.93g/mL, or 0.935g/mL, or 0.94g/mL, or 0.945g/mL, or 0.95g/mL, or 0.955g/mL, or 0.96g/mL, or 0.965g/mL, or 0.97g/mL, or 0.975g/mL, or 0.98g/mL, or 0.985g/mL, or 0.99g/mL, or 0.995g/mL, or 1g/mL, or 1.005g/mL, or 1.01g/mL, or 1.015g/mL, or 1.02g/mL, or 1.025g/mL, or 1.03g/mL, or 1.035g/mL, or 1.04g/mL, or 1.045g/mL, or 1.05g/mL, or 1.055g/mL, or 1.06g/mL, or 1.065g/mL, or 1.07g/mL, or 1.075g/mL, or 1.08g/mL, or 1.085g/mL, or 1.09g/mL, or 1.095g/mL, or 1.1g/mL, or 1.11g/mL, or 1.12g/mL, or 1.13g/mL, or 1.14g/mL, or 1.15g/mL, or 1.16g/mL, or 1.17g/mL, or 1.18g/mL, or 1.19g/mL, or 1.2g/mL, or 1.21g/mL,

or 1.22g/mL, or 1.23g/mL, or 1.24g/mL, or 1.25g/mL, or 1.26g/mL, or 1.27g/mL, or 1.28g/mL, or 1.29g/mL, or 1.3g/mL, or 1.31g/mL, or 1.32g/mL, or 1.33g/mL, or 1.34g/mL, or 1.35g/mL, or 1.36g/mL, or 1.37g/mL, or 1.38g/mL, or 1.39g/mL, or 1.4g/mL, or 1.41g/mL, or 1.42g/mL, or 1.43g/mL, or 1.44g/mL, or 1.45g/mL, or 1.46g/mL, or 1.47g/mL, or 1.48g/mL, or 1.49g/mL, or 1.5g/mL

- **Note:** The density of a low density fluid may be less than or equal to or greater than or equal to one or more or a combination of the following: 0.01g/mL, or 0.05g/mL, or 0.1g/mL, or 0.15g/mL, or 0.20g/mL, or 0.25g/mL, or 0.3g/mL, or 0.35g/mL, or 0.4g/mL, or 0.45g/mL, 0.5g/mL, or 0.51g/mL, or 0.52g/mL, or 0.53g/mL, or 0.54g/mL, or 0.55g/mL, or 0.56g/mL, or 0.57g/mL, or 0.58g/mL, or 0.59g/mL, or 0.6g/mL, or 0.61g/mL, or 0.62g/mL, or 0.63g/mL, 0.64g/mL, or 0.65g/mL, or 0.66g/mL, or 0.67g/mL, or 0.68g/mL, or 0.69g/mL, or 0.70 g/mL, or 0.71g/mL, or 0.72g/mL, or 0.73g/mL, or 0.74g/mL, or 0.75g/mL, or 0.76g/mL, or 0.77g/mL, or 0.78g/mL, or 0.79g/mL, or 0.8g/mL, or 0.805g/mL, or 0.81g/mL, or 0.815g/mL, or 0.82g/mL, or 0.825g/mL, or 0.83g/mL, or 0.835g/mL, or 0.84g/mL, or 0.845g/mL, or 0.85g/mL, or 0.855g/mL, or 0.86g/mL, or 0.865g/mL, or 0.87g/mL, or 0.875g/mL, or 0.88g/mL, or 0.885g/mL, or 0.89g/mL, or 0.895g/mL, or 0.9g/mL, or 0.905g/mL, or 0.91g/mL, or .915g/mL, or 0.92g/mL, or 0.925g/mL, or 0.93g/mL, or 0.935g/mL, or 0.94g/mL, or 0.945g/mL, or 0.95g/mL, or 0.955g/mL, or 0.96g/mL, or 0.965g/mL, or 0.97g/mL, or 0.975g/mL, or 0.98g/mL, or 0.985g/mL, or 0.99g/mL, or 0.995g/mL, or 1g/mL, or 1.005g/mL, or 1.01g/mL, or 1.015g/mL, or 1.02g/mL, or 1.025g/mL, or 1.03g/mL, or 1.035g/mL, or 1.04g/mL, or 1.045g/mL, or 1.05g/mL, or 1.055g/mL, or 1.06g/mL, or 1.065g/mL, or 1.07g/mL, or 1.075g/mL, or 1.08g/mL, or 1.085g/mL, or 1.09g/mL, or 1.095g/mL, or 1.1g/mL, or 1.11g/mL, or 1.12g/mL, or 1.13g/mL, or 1.14g/mL, or 1.15g/mL, or 1.16g/mL, or 1.17g/mL, or 1.18g/mL, or 1.19g/mL, or 1.2g/mL, or 1.21g/mL, or 1.22g/mL, or 1.23g/mL, or 1.24g/mL, or 1.25g/mL, or 1.26g/mL, or 1.27g/mL, or 1.28g/mL, or 1.29g/mL, or 1.3g/mL, or 1.31g/mL, or 1.32g/mL, or 1.33g/mL, or 1.34g/mL, or 1.35g/mL, or 1.36g/mL, or 1.37g/mL, or 1.38g/mL, or 1.39g/mL, or 1.4g/mL, or 1.41g/mL, or 1.42g/mL, or 1.43g/mL, or 1.44g/mL, or 1.45g/mL, or 1.46g/mL, or 1.47g/mL, or 1.48g/mL, or 1.49g/mL, or 1.5g/mL
- **Note:** The density of a high density liquid may be greater than or equal to or less than or equal to one or more or a combination of the following: 0.01g/mL, or 0.05g/mL, or 0.1g/mL, or 0.15g/mL, or 0.20g/mL, or 0.25g/mL, or 0.3g/mL, or 0.35g/mL, or 0.4g/mL,

or 0.45g/mL, 0.5g/mL, or 0.51g/mL, or 0.52g/mL, or 0.53g/mL, or 0.54g/mL, or 0.55g/mL, or 0.56g/mL, or 0.57g/mL, or 0.58g/mL, or 0.59g/mL, or 0.6g/mL, or 0.61g/mL, or 0.62g/mL, or 0.63g/mL, or 0.64g/mL, or 0.65g/mL, or 0.66g/mL, or 0.67g/mL, or 0.68g/mL, or 0.69g/mL, or 0.70 g/mL, or 0.71g/mL, or 0.72g/mL, or 0.73g/mL, or 0.74g/mL, or 0.75g/mL, or 0.76g/mL, or 0.77g/mL, or 0.78g/mL, or 0.79g/mL, or 0.8g/mL, or 0.805g/mL, or 0.81g/mL, or 0.815g/mL, or 0.82g/mL, or 0.825g/mL, or 0.83g/mL, or 0.835g/mL, or 0.84g/mL, or 0.845g/mL, or 0.85g/mL, or 0.855g/mL, or 0.86g/mL, or 0.865g/mL, or 0.87g/mL, or 0.875g/mL, or 0.88g/mL, or 0.885g/mL, or 0.89g/mL, or 0.895g/mL, or 0.9g/mL, or 0.905g/mL, or 0.91g/mL, or .915g/mL, or 0.92g/mL, or 0.925g/mL, or 0.93g/mL, or 0.935g/mL, or 0.94g/mL, or 0.945g/mL, or 0.95g/mL, or 0.955g/mL, or 0.96g/mL, or 0.965g/mL, or 0.97g/mL, or 0.975g/mL, or 0.98g/mL, or 0.985g/mL, or 0.99g/mL, or 0.995g/mL, or 1g/mL, or 1.005g/mL, or 1.01g/mL, or 1.015g/mL, or 1.02g/mL, or 1.025g/mL, or 1.03g/mL, or 1.035g/mL, or 1.04g/mL, or 1.045g/mL, or 1.05g/mL, or 1.055g/mL, or 1.06g/mL, or 1.065g/mL, or 1.07g/mL, or 1.075g/mL, or 1.08g/mL, or 1.085g/mL, or 1.09g/mL, or 1.095g/mL, or 1.1g/mL, or 1.11g/mL, or 1.12g/mL, or 1.13g/mL, or 1.14g/mL, or 1.15g/mL, or 1.16g/mL, or 1.17g/mL, or 1.18g/mL, or 1.19g/mL, or 1.2g/mL, or 1.21g/mL, or 1.22g/mL, or 1.23g/mL, or 1.24g/mL, or 1.25g/mL, or 1.26g/mL, or 1.27g/mL, or 1.28g/mL, or 1.29g/mL, or 1.3g/mL, or 1.31g/mL, or 1.32g/mL, or 1.33g/mL, or 1.34g/mL, or 1.35g/mL, or 1.36g/mL, or 1.37g/mL, or 1.38g/mL, or 1.39g/mL, or 1.4g/mL, or 1.41g/mL, or 1.42g/mL, or 1.43g/mL, or 1.44g/mL, or 1.45g/mL, or 1.46g/mL, or 1.47g/mL, or 1.48g/mL, or 1.49g/mL, or 1.5g/mL, or 1.55g/mL, or 1.6g/mL, or 1.65g/mL, or 1.7g/mL, or 1.75g/mL, or 1.8g/mL, or 1.85g/mL, or 1.9g/mL, or 1.95g/mL, or 2.00g/mL, or 2.05g/mL, or 2.1 g/mL, or 2.2 g/mL, or 2.3 g/mL, or 2.4 g/mL, or 2.5 g/mL, or 2.6 g/mL, or 2.7 g/mL, or 2.8 g/mL, or 2.9 g/mL, or 3.0 g/mL, or 3.1 g/mL, or 3.2 g/mL, or 3.3 g/mL, or 3.4 g/mL, or 3.5 g/mL, or 3.6 g/mL, or 3.7 g/mL, or 3.8 g/mL, or 3.9 g/mL, or 4.0 g/mL, or 4.1 g/mL, or 4.2 g/mL, or 4.3 g/mL, or 4.4 g/mL, or 4.5 g/mL, or 4.6 g/mL, or 4.7 g/mL, or 4.8 g/mL, or 4.9 g/mL, or 5.0 g/mL, 6.0 g/mL, or 7.0 g/mL, or 8.0 g/mL, or 9.0 g/mL, or 10.0 g/mL, or 11.0 g/mL, or 12.0 g/mL, or 13.0 g/mL, or 14.0 g/mL, or 15.0 g/mL, or 16.0 g/mL, or 17.0 g/mL, or 18.0 g/mL, or 19.0 g/mL, or 20.0 g/mL, or 21.0 g/mL, or 22.0 g/mL, or 23.0 g/mL

- **Note:** The tolerance pressure difference of the lower elevation reservoir or ‘second reservoir’ may comprise the maximum design pressure difference between the pressure of a fluid inside the lower elevation reservoir or ‘second reservoir’ and the pressure of a fluid

or material or solid external to or adjacent to said fluid inside the lower elevation reservoir or 'second reservoir' at the same elevation as said fluid inside the lower elevation reservoir or 'second reservoir'.

- **Note:** The tolerance pressure difference of the lower elevation reservoir or 'second reservoir' may be less than, or greater than, or equal to one or more or a combination of the following: 0 Bar, or 0.01 Bar, 0.25 Bar, or 0.5 Bar, or 0.75 Bar, or 1 Bar, or 1.5 Bar, 2 Bar, or 2.5 Bar, or 3 Bar, or 3.5 Bar, or 4 Bar, or 4.5 Bar, or 5 Bar, or 5.5 Bar, or 6 Bar, or 6.5 Bar, or 7 Bar, or 7.5 Bar, or 8 Bar, or 8.5 Bar, or 9 Bar, or 9.5 Bar, or 10 Bar, or 11 Bar, or 12 Bar, or 13 Bar, or 14 Bar, or 15 Bar, or 16 Bar, or 17 Bar, or 18 Bar, or 19 Bar, or 20 Bar, or 21 Bar, or 22 Bar, or 23 Bar, or 24 Bar, or 25 Bar, or 26 Bar, or 27 Bar, or 28 Bar, or 29 Bar, or 30 Bar, or 31 Bar, or 32 Bar, or 33 Bar, or 34 Bar, or 35 Bar, or 36 Bar, or 37 Bar, or 38 Bar, or 39 Bar, or 40 Bar, or 41 Bar, or 42 Bar, or 43 Bar, or 44 Bar, or 45 Bar, or 46 Bar, or 47 Bar, or 48 Bar, or 49 Bar, or 50 Bar, or 55 Bar, or 60 Bar, or 65 Bar, or 70 Bar, or 75 Bar, or 80 Bar, or 85 Bar, or 90 Bar, or 95 Bar, or 100 Bar, or 105 Bar, or 110 Bar, or 115 Bar, or 120 Bar, or 125 Bar, or 130 Bar, or 135 Bar, or 140 Bar, or 145 Bar, or 150 Bar, 160 Bar, or 170 Bar, or 180 Bar, or 190 Bar, or 200 Bar, or 225 Bar, or 250 Bar, or 275 Bar, or 300 Bar
- **Note:** Hydrostatic pressure of a liquid may be calculated using the density of a liquid, the gravitational constant, and the difference in elevation or the difference in elevation which a liquid contiguously transverses. Hydrostatic pressure of a fluid may be calculated using the density of a fluid, the gravitational constant, and the difference in elevation or the difference in elevation which a fluid contiguously transverses. The practical hydrostatic pressure of a liquid may also include frictional losses and other potential pressure losses which may occur in a real system, which may be calculated using fluid dynamics equations and / or simulation tools known in the art.
- **Note:** In some embodiments, the low density fluid may comprise a gas or supercritical fluid. For example, the low density fluid may comprise air and air may comprise a gas and / or a supercritical fluid. At pressures greater than about 55 Bar, air may comprise a supercritical fluid.
- **Note:** The pressure difference between a liquid or fluid stored in a higher elevation reservoir and the fluid or material or solid external to or adjacent to said higher elevation reservoir at the same elevation may be less than, or equal to, or greater than one or more or a combination of the following: 0 Bar, or 0.01 Bar, 0.25 Bar, or 0.5 Bar, or 0.75 Bar, or

1 Bar, or 1.5 Bar, 2 Bar, or 2.5 Bar, or 3 Bar, or 3.5 Bar, or 4 Bar, or 4.5 Bar, or 5 Bar, or 5.5 Bar, or 6 Bar, or 6.5 Bar, or 7 Bar, or 7.5 Bar, or 8 Bar, or 8.5 Bar, or 9 Bar, or 9.5 Bar, or 10 Bar, or 11 Bar, or 12 Bar, or 13 Bar, or 14 Bar, or 15 Bar, or 16 Bar, or 17 Bar, or 18 Bar, or 19 Bar, or 20 Bar, or 21 Bar, or 22 Bar, or 23 Bar, or 24 Bar, or 25 Bar, or 26 Bar, or 27 Bar, or 28 Bar, or 29 Bar, or 30 Bar, or 31 Bar, or 32 Bar, or 33 Bar, or 34 Bar, or 35 Bar, or 36 Bar, or 37 Bar, or 38 Bar, or 39 Bar, or 40 Bar, or 41 Bar, or 42 Bar, or 43 Bar, or 44 Bar, or 45 Bar, or 46 Bar, or 47 Bar, or 48 Bar, or 49 Bar, or 50 Bar, or 55 Bar, or 60 Bar, or 65 Bar, or 70 Bar, or 75 Bar, or 80 Bar, or 85 Bar, or 90 Bar, or 95 Bar, or 100 Bar, or 105 Bar, or 110 Bar, or 115 Bar, or 120 Bar, or 125 Bar, or 130 Bar, or 135 Bar, or 140 Bar, or 145 Bar, or 150 Bar, 160 Bar, or 170 Bar, or 180 Bar, or 190 Bar, or 200 Bar, or 225 Bar, or 250 Bar, or 275 Bar, or 300 Bar

- **Note:** In some embodiments, the lower elevation reservoir may comprise two or more different reservoirs. For example, in some embodiments, the lower elevation reservoir may comprise at least one reservoir for low density liquid and at least one reservoir for high density liquid. For example, in some embodiments, the lower elevation reservoir may comprise a separate reservoir for low density liquid and a separate reservoir for high density liquid. For example, in some embodiments, the lower elevation reservoir may comprise two separate tanks, one tank for storing low density liquid and one tank for storing high density liquid. For example, in some embodiments, the lower elevation reservoir may comprise two separate tanks, one tank for storing low density liquid and one tank for storing high density liquid, where each tank comprises a bladder tank. For example, in some embodiments, the lower elevation reservoir may comprise two separate tanks, one tank for storing low density liquid and one tank for storing high density liquid, where each tank comprises a rigid tank. For example, in some embodiments, the lower elevation reservoir may comprise two separate tanks, one tank for storing low density liquid and one tank for storing high density liquid, where each tank comprises a rigid tank, or a bladder tank, or a combination thereof. An example of the some of the presently described embodiments may include, but is not limited to, Figures 77 and 78.

[0650] The low density liquid and / or high density liquid in some embodiments may comprise stored fuel. For example, the stored fuel may comprise, including, but not limited to, one or more or any combination of the following: butane, or propane, or LPG, or ethane, or LNG, or diesel, or kerosene, or gasoline, or petroleum ether, or ammonia, or hydrogen, or hydrogen derivative, or ethanol, or methanol. In some embodiments, the stored fuel may comprise a carrier fuel. For

example, the stored fuel may comprise a hydrogen carrier, which may include, but are not limited to, one or more or any combination of the following: Methylcyclohexane, or Toluene, or methanol, or ammonia, or hydrazine. If desired, the stored fuel may be employed in other applications in addition to liquid displacement energy storage.

[0651] For example, the stored fuel may be employed as a fuel source for a combustion power plant. The combustion power plant may comprise a floating power plant, or onshore power plant, or offshore power plant, or any combination thereof. The combustion power plant may involve a gas turbine, or an internal combustion engine, or a combined cycle, or a Rankine cycle, or cogeneration, or Peaker plant, or open cycle engine, or closed cycle engine, or heat engine, or any combination thereof. The combustion power plant may be operated as desired. For example, the combustion power plant may operate when electricity demands exceed the power capacity of the pump and / or generator. For example, the combustion power plant may operate when the gravitational energy storage system is fully discharged or almost fully discharged. For example, the combustion power plant may operate in the event of an emergency. For example, the combustion power plant may substantially extend the potential duration of the energy storage system. For example, in some instances, liquid displacement energy storage may provide 90% of annual energy storage needs, and the combustion power plant may provide 10% of annual energy storage needs. For example, in some instances, liquid displacement energy storage may provide 95% of annual energy storage needs, and the combustion power plant may provide 5% of annual energy storage needs. For example, in some instances, liquid displacement energy storage may provide 80% of annual energy storage needs, and the combustion power plant may provide 20% of annual energy storage needs. Due to the significant potential fuel storage in a liquid displacement energy storage system, integration of liquid displacement energy storage with a combustion power plant may result in the creation of an energy storage system high round trip efficiency energy storage and multiple months of available energy storage duration. Integration of liquid displacement energy storage with a backup combustion power plant may result in an end-to-end energy storage solution for the creation of an electricity grid powered by near 100% or 100% renewable energy, especially if the stored fuel comprises a renewable fuel or a fuel derived from renewable energy. Integration of liquid displacement energy storage with a backup combustion power plant may result in an end-to-end energy storage solution for the creation of an electricity grid powered by near 100% or 100% CO₂ emissions-free energy, especially if the stored fuel comprises a carbon-free, or low carbon, or renewable, or carbon neutral fuel.

[0652] In some embodiments, fuel or makeup fuel may be provided from external sources, and / or may be provided via ship, or pipeline, or any combination thereof. In some embodiments, fuel or makeup fuel may be provided from internal or on-site sources, and / or may be synthesized or otherwise generated internally or onsite. For example, in some embodiments, a low density liquid comprising hydrogen, or liquid hydrogen, or ammonia, or methanol, or ethanol, or butane, or kerosene, or methane, or LPG, or any combination thereof may be generated onsite. For example, in some embodiments, a low density fluid comprising hydrogen, or liquid hydrogen, or ammonia, or methanol, or ethanol, or butane, or kerosene, or methane, or LPG, or any combination thereof may be generated onsite. For example, in some embodiments, hydrogen, or ammonia, or methanol, or ethanol, or butane, or kerosene, or methane, or LPG, or any combination thereof may be generated onsite. For example, in some embodiments, hydrogen, or ammonia, or methanol, or ethanol, or butane, or kerosene, or methane, or LPG, or any combination thereof may be generated onsite, using, for example, electricity, or renewable electricity, or water, or air, or nitrogen, or carbon dioxide, or any combination thereof.

[0653] In some instances, water may be employed as a low density liquid. For example, in some embodiments, the low density liquid may comprise water and the high density liquid may comprise a salt water brine. For example, in some embodiments, the low density liquid may comprise water and the high density liquid may comprise a fluorocarbon.

[0654] In some instances, the high density liquid, or high density fluid, or low density liquid, or low density fluid, or any combination thereof may comprise a solid-liquid mixture, or an emulsion, or suspension, or both. For example, an example solid-liquid mixture may comprise milk. For example, a solid liquid mixture may comprise, including, but not limited to, one or more or any combination of the following: water, or aqueous solution, or coal, or fly ash, or lime stone, or zinc tailings, or rock phosphate, or gilsonite, or copper concentrate, or iron ore, or talc, or Kaolin, or cement, or concrete, or aggregate, or dense solid, or high density solid, or a solid with a higher density than the low density fluid, or a solid with a higher density than water, or a fluorocarbon, or halogenated reagent, or a halogen. For example, a solid liquid mixture may comprise, including, but not limited to, one or more or any combination of the following: water, or aqueous solution, or low density solid, or plastic, or hydrocarbon. It may be desirable for the high density liquid, or high density fluid, or low density liquid, or low density fluid, or any combination thereof to be essentially incompressible fluids. In some descriptions herein, a fluid may be described as a 'liquid'. A 'liquid' may comprise any fluid comprising at least a portion of a liquid, which may include, but are not limited to, liquids and / or solid-liquid mixtures.

[0655] Some example embodiments related to gas pockets and concave structures: An example embodiment may involve ‘walls’ connected to the bottom or sides of a liquid structure. A liquid structure may include, but is not limited to, one or more or a combination of the following: floating structure, a dock, buoy, platform, float, boat, flat bottom boat, skiff, or surface structure. A liquid structure may also include structures which are anchored to land or at least partially supported by land, while also being in or near or in contact with water or immersed in water or in contact with water or in contact with another liquid.

[0656] In an example embodiment, the structure may be a dock (please note: a dock is provided as an example floating structure, the elements of the embodiment described herein may be applicable to other floating or non-floating structures described herein). Connected or as a component of the dock or as a feature of the shape of the bottom of the dock are ‘walls’ which may be connected to the side or bottom of the dock or near the perimeter of the bottom of the dock. Alternatively, the shape of the bottom of the dock may be tailored to have said ‘walls’, as in, for example, said ‘walls’ may be part of the shape of the dock rather than a connected separate material. Said ‘walls’ may protrude beyond the vertical water depth of most or all of the floating dock in contact with the water. The connection of the ‘walls’ to the structure may be ideally air or water tight. Said ‘walls’ may simply comprise a concave structure or protruding portions of a concave structure.

[0657] Said walls may result in the formation of concave region or cavity located, for example, near the bottom of a floating structure or comprise most of the bottom of a floating structure. In the present embodiment, a gas or low density liquid or other fluid may occupy at least a portion of said concave region. Said fluid may include, but is not limited to, one or more or a combination of the following: air, nitrogen, water vapor, methane, hydrogen, flue gases, carbon dioxide, oxygen, inert gas, argon, helium, practically water insoluble gas, hydrocarbon, butane, propane, ethane, ozone, or a combination thereof. For the purposes of example, said fluid may be referred to as a ‘gas’, although a gas may be simply an example state of a fluid, and other fluid states may be employed, which may include, but are not limited to, liquid, or supercritical, or any combination thereof. The gas may be at least temporarily or semi-permanently or practically permanently ‘trapped’ in said concave region. Said ‘trapped’ gas in said concave region may be referred to as a ‘gas pocket’ or an ‘air pocket’. Said gas remains in said concave region due to, for example, 1) greater density of water than the gas; and/or 2) the gas’ practical inability to pass through the water / gas interface; and/or 3) the relative gas tightness or gas tight seal of the concave region.

[0658] An operating principle of the air pocket may be demonstrated by using a simple empty drink cup and a container filled with water. When an empty drink cup is flipped upside-down and submerged beneath the surface of the water in an upside-down position, air in said drink cup may be trapped inside said drink cup as water may be unable to replace said air because the air cannot escape upward through the drinking cup. Said trapped air may be an example of an air pocket and the region inside the cup where the air is trapped may be an example of a concave region or cavity. An example application where said air pocket effect has been employed in prior art may include ‘diving bells’.

[0659] Said gas pocket or air pocket may result in the formation of a separation or non-contiguous separation between the water and at least a portion of the surface of the concave region. Water may be separated from contact with at least a portion of the solid surface of the of the concave region due to the physical separation or barrier of the gas pocket between the water and said solid surface. A significant portion of the surface area of the solid surface of the concave region may be in contact with said gas pocket. A significant portion of the surface area of water displaced by the air pocket may be in contact with the air pocket at an air – water interface. Said concave region or surface area in contact with said gas pocket may comprise a significant portion of or nearly all the surface area of the bottom of, for example, the bottom of a surface structure. Said concave region or surface area in contact with said gas pocket may comprise a significant portion of or nearly all the surface area which may be exposed to or vulnerable to or would otherwise be in contact with water or other liquid. Said significant portion may comprise greater than 5%, or greater than 10%, or greater than 20%, or greater than 30%, or greater than 40%, or greater than 50%, or greater than 60%, or greater than 70%, or greater than 80%, or greater than 90%, or greater than 95% of the bottom of the surface of a structure in contact with a liquid or water body.

[0660] Fouling or scaling or growth formation may be inhibited by said separation or non-contiguous separation between the liquid and at least a portion of the surface of the concave region resulting from, for example, said gas pocket. Fouling or scaling or growth formation generally occurs in a water environment when water is in direct contact with a solid surface. Said air pocket enables a substantial surface area of water, which may otherwise be in contact with solid surface, to be in contact with a water – gas or water – air interface rather than with a solid surface. Said gas separation or air barrier prevents liquid-borne or water-borne foulants or scalants or growths to adhere the said solid surface. Said concave region may comprise at least a portion of the surface area of the bottom of a floating structure or structure in contact with liquid. Said

concave region may comprise a substantial portion or most or almost all the surface area of the bottom of said floating structure or structure in contact with liquid, which may enable a substantial reduction in fouling or scaling or growth formation relative the same structure without a gas pocket or air pocket.

[0661] Foulants or scalants or growths generally adhere to surfaces from water through direct contact with a solid surface. Water-borne foulants or scalants or growths generally cannot pass through air or other gas to a solid surface. In an instance where water-borne foulants or scalants or growths are somehow capable of passing through air or other gas to a solid surface, it is important to note that mass transfer through said gas may be orders of magnitude less than if water was in direct contact with a solid surface. As a result, water-borne foulants or scalants or growths may have insufficient mass transfer to conduct substantially any or relatively equivalent fouling, scaling, or growth in a gas or air environment relative to an environment of direct solid surface contact with water.

- Gas pockets or concave regions or both may increase or decrease stability. Stability may be increased, for example due to ‘suction’ effect or attraction created by a structure with gas-solid interface on one side and solid-water interface on the other side. Stability may be increased by, for example, reducing the center of gravity of the dock by, for example, adding weight to the ‘walls’ of a concave region. By adding weight to the walls of a concave region or near the bottom of the structure, the structure may be less likely to tilt sufficiently to lose gas in a gas pocket, in the event of, for example, a weight imbalance on the structure or a large wave. Gas pockets or concave regions may decrease stability by potentially increasing center of gravity. If a structure is in an environment with significant waves or the potential for rough water, it may be desirable, for example, to incorporate a gyroscopic stabilizer or stabilizing anchors or stabilizing weights or stabilizing earth connected structures to increase stability or minimize tilting.
- Gas pockets or concave regions or surface modifications which enable gas pockets may be employed to prevent corrosion or degradation. For example, a corrosion sensitive material or device may be placed in a gas pocket when stored underwater. For example, the propeller of a boat may be surrounded a gas pocket when the propeller or boat is not in use, which may be enabled by encasing or surrounding said propeller with a concave region. For example, underwater hydraulic

equipment or underwater trim-tabs may be surrounded a gas pocket when, for example, not in use.

- A tube may be placed in the gas pocket or the concave region and gas (for example, including, but not limited to, gases described herein, such as air or nitrogen) may be pumped into the concave regions using said tube and / or a gas pump (which may be connected to said tube). One of the openings of the tube may be placed inside said concave region or below said concave region. The initial pumping of gas into said concave region may enable the formation of a gas pocket in said concave region. After the formation of a gas pocket, additional gas may be pumped into said region to, for example, including, but not limited to, one or more or a combination of the following: expand said gas pocket, to replace gas which may have escaped from said gas pocket, or enable an overflow or spillover of excess gas from said gas pocket and concave region.

[0662] Said concave region or gas pocket may be infiltrated with water on, for example, an occasion of a large wave or when a structure is tilted at a significant angle. It may be advantageous for said water contact to be temporary or of as short duration as possible to minimize potential scaling or fouling or corrosion resulting from, for example, water contact. One means of potentially minimizing frequency of water contact may comprise pumping air or other gas into said concave region or cavity using, for example, a tube or pressurized air tank. Said air or other gas may be pumped continuously into said concave region or may be pumped into said concave region only on certain occasions. For example, said certain occasions may comprise when the gas pocket or air pocket is at risk of losing air or at risk of water infiltration into the concave region. For example, said certain occasions may comprise when a structure tilts beyond a specified angle, which may be triggered or measured, for example, using devices for measuring angle change or movement known in the art. For example, said certain occasions may comprise when a portion of the solid surface of said concave region is wetted or at least partially wetted or in contact with water, which may be triggered or measured, for example, using a water or wetting sensor or similar devices known in the art.

[0663] It may be desirable for the ‘walls’ to be durable and capable of handling the weight of the dock or multiple docks and resistant to the abuse from other objects or elements. For example, said wall may comprise an a ‘skirt’, for example, wherein the material may be structurally bendable, however can store an air pocket. Said ‘skirt’ may be similar to the ‘skirt’ employed in hovercrafts, although, unlike hovercrafts, the skirt may remain in part or in whole beneath the surface of the water.

[0664] An example durable wall comprises a tube connected to the bottom of the dock and attached, for example, near the outside perimeter of the dock bottom and may be surrounding the outside perimeter of the dock. To prevent damage to the 'walls', the tube may be collapsible when the dock is being moved. The tube may be inflated or may become more rigid using, for example, including, but not limited to, pneumatic or hydraulic pressure means, such as pneumatic or hydraulic pressure or filling with a pneumatic or hydraulic fluid. Said tube may be connected to the dock in a fashion which prevents air or water from passing through the connection between the dock and the tube 'walls'.

[0665] The present invention and / or elements of the present invention, which may include, but are not limited to, 'Wall', gas pocket, concave region, tube, gas pump or air pump, and / or other elements of the embodiments described herein, may be retrofitted onto pre-existing structures or may be an element of new structures.

[0666] The present invention may also be applicable to preventing or minimizing foulants or scalants or growths in non-aqueous liquid environments.

[0667] Portions of a floating structure may be in contact with water or liquid, for example, which may include solid surfaces outside a concave region or gas pocket. Said solid surfaces in contact with water or liquid may be susceptible to growths, fouling or scaling. It is important to note that a large portion of the solid surface area beneath the surface of the water or liquid may be in contact with a gas pocket, and, as a result, may be unsusceptible or less prone to the formation of growths, fouling or scaling. This may have an effect of significantly reducing or eliminating the formation of growths, fouling or scaling on most of the subsurface surface area of a solid structure. Surfaces in contact with water or liquid may have the formation of growths, fouling or scaling, however it may be important to note 1) side-walls are generally easier to clean/scrub than the bottom / underbody / underbelly of a floating structure; 2) the total amount of the formation of growths, fouling or scaling may be significantly less than if the present invention was not employed; 3) an air curtain may be created which minimizes growth formation on regions not protected by an air pocket by pumping excess air into said concave region and facilitating the formation of small air bubbles, which may rise along the sides of the structure.

[0668] Water may refer to a body of liquid. Said body of liquid may include, but is not limited to, a body of liquid containing at least a portion of water including salt water. Said body of liquid may include, but is not limited to, marine environments, aquatic environments, rivers, lakes, brine pools, frac water, waste water, oil storage, chemical storage, or other liquids environments.

[0669] A gas pocket may be trapped or stationary in low turbulence or minimal turbulence or non-turbulent conditions. Non-turbulent conditions may include an environment where the water is calm and non-moving to the naked eye and the structure in said water is also non-moving to the naked eye. Low turbulence or minimal turbulence conditions may include an environment where the water is calm and moving to the naked eye and / or the structure in said water is calm and moving to the naked eye. In a low turbulence environment, although there is discernable movement, the movement of the water or structure is insufficient for more than 10%, or more than 20%, or more than 25%, or more than 30%, or more than 40%, or more than 50% of the gas in the gas pocket to escape from beneath the structure in a 30 second period. It is important to note, said gas escape may not include intentional removal of gas from said gas pocket or the escape of gas through a tube interconnected to said gas pocket.

- Some embodiments may be employed to encourage growth formation, such as certain forms of growth. For example, embodiments described herein, such as gas pockets, may be formed in a certain region to kill an invasive species of algae or the eggs of an invasive fish, other potentially harmful water borne life form. For example, a gas pocket may enable localized oxygenation. For example, a gas pocket may enable localized de-oxygenation. For example, a gas pocket may enable localized cooling, which may comprise evaporative cooling, which may increase the longevity of or improve the health of, for example, coral. For example, a gas pocket may enable localized pH adjustment, such as pH increase by CO₂ removal or CO₂ gas stripping.

EXAMPLE EXEMPLARY EMBODIMENTS:

[0670] System for fouling and scaling prevention on water structures comprising:

- A structure containing a concave region
- Wherein said concave region contains a gas pocket
- Wherein said gas pocket results in a non-contiguous separation between a water and at least a portion of the surface of said concave region

[0671] System for fouling and scaling prevention on water structures comprising:

- A structure containing a cavity
- Wherein said cavity contains a gas pocket
- Wherein said gas pocket results in a non-contiguous separation between liquid and at least a portion of said cavity

EXAMPLE EXEMPLARY SUB-EMBODIMENTS

- Wherein said non-contiguous separation inhibits the formation of scalants, foulants, and growths on the solid surfaces in contact with said region occupied by said gas pocket
- Wherein a tube with an opening located beneath or inside said concave region is interconnected to a pressurized gas source
- Wherein said pressurized gas source may include an air pump, a gas pump, a pressurized gas line, or a combination thereof
- Wherein said tube is connected to a valve which allows control over gas entering or exiting said gas pocket through said tube
- Wherein at least a portion of the solid surface area in contact with said gas pocket is separated or not in direct contact with water for greater than 30%, or greater than 40%, or greater than 50%, or greater than 60%, or greater than 70%, or greater than 80%, or greater than 90%, or greater than 95% of the time said structure is in said water
- Wherein said water comprises a body of liquid
- Wherein said gas pocket displaces liquid
- Wherein said gas pocket is trapped or stationary in low turbulence or minimal turbulence or non-turbulent conditions
- Wherein gas may be pumped into said gas pocket continuously or semi-continuously or on occasion where gas needs to be replenished
- Wherein gas is pumped into said gas pocket in excess of the volumetric capacity of said cavity or concave region, resulting in spillover bubbles
- Wherein said spillover bubbles reduce fouling on solid surface area not in direct contact with said gas pocket
- Wherein said spillover bubbles are methodically dispersed along said solid surface area not in direct contact with said gas pocket using shape modifications to sections of the structure
- Wherein said shape modifications may include perforations, dimples, microscopic modifications, surface morphology, or macroscopic modifications
- Wherein the height of said structure over the surface of the water can be adjusted by increasing or decreasing the volume of gas in said concave region or cavity
- Wherein said concave region or cavity is retrofitted onto a pre-existing structure
- Wherein said concave region or cavity is an aspect of the shape of a pre-existing structure
- Wherein said concave region or cavity is an aspect of the shape of a new structure

- Wherein the shape or size or strength or rigidity of said concave region or cavity may be adjustable
- Wherein said adjustability may include controlled forming or collapsing of said concave region or the 'walls' of said concave region
- Wherein said adjustability may include controlled forming or collapsing of said concave region or the 'walls' of said concave region using pneumatic or hydraulic means
- Wherein said adjustability may include controlled volume or depth or surface area of said concave region
- Wherein the volume, or shape, or surface area, or depth of said gas pocket are adjustable
- Wherein said gas pocket adjustability involves one or more or a combination of the following: the ability to add or remove gas from said gas pocket, the ability to change the shape or contour of said gas pocket or concave region, the ability to adjust the shape or size of the 'walls' of the concave region
- Wherein said gas pocket contains a non-water liquid in addition to or instead of a gas
- Wherein the surface of said gas pocket is hydrophobic or contains a hydrophobic coating
- Wherein said gas pocket or concave region or cavity may function as a diving bell or temporary shelter or storage region
- Wherein said tube is connected to a check valve which allows gas (such as air) to enter said tube and/or said concave region, although does not allow air to be released from said region

Figure Key:

- **'1' or '(1)'**: Top section of a floating platform or dock
- **'2' or '(2)'**: Floats or pontoons, bottom section of a floating platform or dock
- **'3' or '(3)'**: Gas or air pocket, which may be in the concave region on the underside or bottom of '2'
- **'4' or '(4)'**: Liquid body, such as a body of water or oil
- **'5' or '(5)'**: Extended walls, which may extend beyond the vertical depth of the air pocket
- **'6' or '(6)'**: Air or gas bubble curtain up the side walls of '2' in contact with water. '6' may result from gas being pumped into a concave region, and the gas pocket exceeding the volume of the concave region's gas capacity. The bubble curtain may be facilitated by perforations or dimples in the side walls. A bubble curtain may reduce growth formation on surfaces not in contact with the gas pocket.
- **'7' or '(7)'**: Air or gas pump connected to tubing (lines with arrows). Tubing may interconnect said gas or air pumped by said pump with the concave region.

[0672] **Figure 1:** An example dock with a concave region ‘gas pocket’ (‘3’) on the bottom of each float or pontoon. The gas pocket may enable a large portion of the surface area on the bottom of the dock, or the surface area of the dock in contact with the air pocket, to have minimal or no levels of foulants, scalants, or growths.

[0673] **Figure 2:** An example dock with a concave region ‘gas pocket’ (‘3’) on the bottom of each float or pontoon. A tube may be placed beneath or connected to bottom of dock. Air or other gas may be pumped into the tube, which directs gas into the gas pocket. If the volume of gas exceeds the volume of the concave region or cavity, bubbles may travel up side of dock, which may, if desired, form a bubble curtain along the side of the dock (‘6’). Said bubbled curtain may be facilitated, for example, by placing dimples or perforations in the ‘walls’ of concave region. Dimples or perforations may be located near the bottom of the vertical depth of said ‘walls’ of the concave region. Said bubble curtain may be desirable to minimize fouling, scaling, and growths outside of the gas pocket. If a continuous bubble curtain is desirable, a continuous flow of pumped air may be required.

[0674] **Figure 3:** An example embodiment with extended ‘walls’, which may be employed to prevent air or gas losses in the event of, for example, waves, turbulent water, or a significant change in the angle of the dock. Extended walls may extend to a depth beyond the depth of the air pocket. Extended walls may be weighted, if desired, to reduce center of gravity. It may be desirable to prevent the air pocket from extending to the full depth of the extended walls (for example: to ensure the dock is stable), in which case it may be desirable to include small perforations in certain parts of the extended walls. Air or other gas may need to be pumped into the air pocket less frequently or on fewer occasions in embodiments with extended walls.

[0675] **Figure 4:** An example embodiment where changing the volume of gas in a gas pocket adjusts the height above the liquid surface and/or angle of a floating structure, such as a dock. Figure 4 may show the height of a dock above the surface of water being increased by pumping air into two concave regions, increasing the volume of an air pocket and displacing water from the concave regions. The present embodiment may be advantageous for increasing or decreasing the height or reducing the draft of a dock. Advantageously, relatively little energy may be required to increase the height of the dock due to, for example, the potentially low air pressure in the concave region due to, for example, the relatively small head height. Advantageously, no moving parts are required to be in contact with the liquid.

[0676] **Figure 5:** An example embodiment where changing the volume of gas in a gas pocket adjusts the height above the liquid surface and/or angle of a floating structure, such as a dock.

Figure 5 may show the height of a dock above the surface of water being decreased by releasing air from concave regions, increasing the volume of an air pocket and displacing water from the concave regions. The present embodiment may be advantageous for increasing or decreasing the height or reducing the draft of a dock.

Tidal Power System, or Energy Storage System, or any Combination Thereof

[0677] **Description:** The present embodiments may relate to systems and methods for generating energy from the change in water level due to tides. Some embodiments may be applicable to, for example, a tidal power energy generation system, which generates energy from change in water level due to, for example, tides. Some embodiments may involve using the displacement of air or other fluid from a storage region due to a rise in water level due to tides to generate energy, such as electricity. Some embodiments may involve using the movement of air or other fluid into a storage region due to a decrease in water level due to tides to generate electricity. The movement of air or displacement of air may be transferred through one or more tubes to, for example, the surface and/or may be converted to electricity using, for example, a pneumatic generator. The generation of electricity, pneumatic pump, pneumatic generator, and/or other components may be located on the surface outside the water or storage region if desired. Another gas or fluid other than air or in addition to air or in combination with air may be employed if desired. Said storage region may comprise a water or air or fluid impermeable material or structure with a concave region containing space which can be occupied by a fluid. Said concave region may be occupied by a porous material, for example, sand or rocks or cinder blocks or plastic bottles or packing material, which may contain space which can be occupied by a fluid, such as water or air. Said storage region may comprise a water or air tight liner or tarp which forms a concave region over a portion of sand or rock or cinder blocks or plastic bottles or packing material or solid material with space which can be occupied by a fluid, such as water or air. Said storage region may comprise a rigid structure such as an old ship, or a plastic container. Said storage region may comprise a bag, or bladder, or flexible structure, which may be expanded when filled with a gas or a low density liquid at, for example, lower tides, and collapsible when said gas or low density liquid is released through, for example, a generator, at higher tides. Said concave region may comprise open space which may be occupied by a fluid, such as water or air. Said concave region may be positioned such that the concave region faces the direction of the earth's surface (e.g. the direction of the force of gravity) such that a lower density fluid may be trapped in said concave region if desired. Said concave region may contain a tube with an opening inside said concave region. Said tube may be interconnected to the surface, where it may be connected

to a pneumatic pump or generator or a hydraulic pump or generator. Said tube may be placed under and around said concave region, as opposed to, for example, through the material of said storage region, as this may reduce the likelihood of leaks through said storage region.

[0678] The concave region or storage region may comprise infrastructure employed for another purpose, which may include, but is not limited to, one or more or a combination of the following: a sewer system, a drainage system, a runoff water system, a wastewater system, a drainage pipe, an intake pipe, an outflow pipe, or a water storage region.

[0679] A concave region or storage region may be filled with a porous material fill. Said porous material fill may comprise, including, but not limited to, one or more or a combination of the following: sand, gravel, rock, packing material, or cinderblock, or plastic bottles, or plastic containers, or plastic buckets, or interconnected cinderblock, or interconnected plastic containers, or interconnected packing material.

[0680] The concave region or storage region may be built into or may be a component of a pre-existing or new marine structure. For example, a concave region or storage region (which may be integrated with an air tube and pneumatic generator / pump) may be fabricated as a component causeway, breakwall, building foundation, landfill or land expansion, or artificial island. Advantageously, the subsurface of waterfront land, which is rarely seen or utilized after construction, may be transformed into a means for generating renewable electricity from the tides or changes in water level of a water body.

[0681] For example, a concave region or storage region may be constructed as part of a causeway or landfill or artificial island in three general steps: 1) Air tubes may be placed in the region where the marine structure will be constructed. The air tubes may have an end which is located at a vertical height near the vertical height of the eventually constructed concave region or storage region. If advantageous, a water pipe may be placed in the region where the marine structure will be constructed to facilitate water flow in the eventually constructed concave region or storage region. Alternatively, water seepage or permeate may be the sole source of water flow if, for example, a water pipe is not employed. 2) Porous material fill, such as rock, or sand, or cinder block, or other fill materials, or other porous fill materials described herein, or a combination thereof, may be added. Said fill materials may comprise the interior of the concave region or storage region. Said fill materials may surround the air tubes. It may be desirable for said fill materials to surround, although not substantially or completely block or kink or clog an air tube. Fill materials may be carefully placed to match a design or the contour of the storage region or concave region liner. 3) A liner may be placed over said fill materials and pipe. It may

be desirable for the liner to match the contour of the fill materials and it may be desirable for the liner to surround the fill materials for the full vertical depth of the fill materials or storage region. A liner may include, but is not limited to, one or more or a combination of the following: a HDPE liner, or LDPE liner, or aluminum liner, or steel liner, or metal coated liner, or metal liner, or cement liner, a cement layer, or clay liner, or landfill liner, or pond liner, or lake liner, storage basin liner, or a nylon liner, or geosynthetic liner, or PVC liner, or bag, or fabric, or textile, or mesh, or high strength polymer liner, or woven liner, or braided liner, or liner comprising multiple layers of materials for strength and fluid tightness, or tarp.

[0682] After the liner has been placed, materials comprising the rest of the marine structure may be added to, for example, construct the marine structure. If advantageous, buffer materials may be added to the top or bottom of the liner to minimize potential wear and tear or prevent the formation of perforations in the liner. Said buffer materials may include, but are not limited to, one or more or a combination of the following: sand, or burlap, or twine, or woven nylon, or Kevlar, or gravel, or clay, or mud, or foam, or cement, or concrete, or mesh, or fabric, or textile, or rubber. Advantageously, it is possible to construct the present tidal power system with no moving parts beneath the surface of the water, or underground, or inside the storage region or cavity.

[0683] For example, a concave region or storage region may be constructed as an aspect of an artificial reef or from vessels or structures which may otherwise be sunk. For example, a concave region or storage region may be constructed from using upside-down vessel or ship or boat or tank or barge. Advantageously, the hull of a ship may already be fluid tight, although additional patching or re-enforcement may be employed if desired. An example implementation may involve one or more of the following steps: 1) placing tubing and / or water pipes inside said vessel. An opening of the air tubing may be placed or attached near the bottom of the vessel (which may be near the eventual top of the storage region or concave region when said vessel becomes a storage region or concave region). Water tubing may be employed to facilitate water flow in and out of the storage region or concave region. 2) Placing porous filling material into at least a portion of said vessel. Said porous filling material may be employed to prevent the vessel from floating when the vessel open space is occupied by air. Alternatively or additionally, said vessel may be prevented from floating by using anchors and lines, which may be evenly distributed across the vessel. If necessary, a portion of the remaining air space inside the vessel may be filled with water to promote sinking. 3) Flipping said vessel upside down and placing said vessel at or near the bottom of the water body. It may be desirable for the fill material to be at least partially contained

in the vessel to prevent significant uncontrolled spilling of fill material. Fill material may be contained due to at least partially covered compartments inside said vessel. Alternatively or additionally, said fill materials may be contained using a fabric or mesh or twine or net. It may be advantageous to conduct this step when the vessel is near the bottom of said water body to, for example, minimize uncontrolled spilling of fill material. Air pipes may be connected to an air pump or pneumatic generator located near, at, or above the surface. Water pipes may be open to the surrounding water body. Advantageously, if a storage region or concave region is located near the bottom of a water body, it may experience near or close to the full hydraulic head of the water body throughout the energy generation step, although this may be dependent on the vertical height of said concave region relative to the depth of the water body and water level difference between low and high tide.

[0684] Some embodiments may generate electricity from the difference in hydraulic pressure in a storage region in a water body due to the change with water level, which may be due to tides. An embodiment may involve a storage region beneath the surface of a water body. During relatively lower water levels or tides, air may be pumped into the storage region using, for example, one or more tubes, displacing water in said storage region. During relatively higher water levels or tides, water may be allowed to displace air from said storage region, and said air may pass through, for example, one or more tubes into pneumatic generator, generating useful work or electricity. It is important to note that at higher water levels or tides, the hydraulic pressure in the storage region may be significantly greater than the hydraulic pressure in the storage region during lower water levels or tides. Net energy or electricity may be generated due to, for example, the significantly greater amount of energy or electricity generated from air being displaced into a generator at higher tides or water levels than the energy or electricity required to pump air into said storage region during lower water levels or tides. Net energy or electricity generated may comprise the difference in between the energy generated during higher water levels or tides compared to the energy consumed during lower water levels or tides.

[0685] Embodiments may generate electricity during one or more of the tide cycles. For example, some embodiments may generate electricity during four tide cycles in a ~1 day period (for example: 2 high tides, two low tides) - an example of this may be an embodiment employing an underground cavity with depth in the range of the ocean water level at higher or lower or both tides. For example, some embodiments may generate electricity during two tide cycles in a ~1 day period (for example: 2 high tides) - an example of this may be an embodiment employing an under water storage region at below or near or about same water depth of the low tide depth in a

region. For example, some embodiments may generate electricity during less cycles than their available capacity – an example of this may be an embodiment employing an underground cavity with depth in the range of the ocean water level at higher or lower or both tides wherein the process generates electricity during only higher tides. An embodiment which only generates electricity during higher tides may be advantageous as some cavities may not be structurally suitable for partial vacuums, which may be required to generate electricity during all four tide movements during a day.

[0686] The process may employ a hydroelectric or hydro generator if advantageous. It is important to note to minimize costs and maximize longevity, it may be advantageous to employ a pneumatic generator powered by air displacement.

[0687] Cavity, storage region, or concave region may be analogous or synonym terms.

[0688] Some embodiments may pertain to tanks applicable to storing low density fluids underwater. For example, some embodiments may relate to rigid or flexible structures. For example, some embodiments may relate to tanks or storage regions containing a porous solid medium, wherein a low density fluid may be stored in the pores of said porous medium. For example, some embodiments may relate to tanks or storage regions containing a porous solid medium, wherein low density fluid is stored in said porous medium by pumping or otherwise directing a low density fluid into said porous medium to displace a higher density fluid stored in said porous medium. For example, some embodiments may employ a storage reservoir comprising a porous medium, wherein the density or weight of said porous medium may reduce the buoyancy of said storage reservoir. For example, some embodiments may employ a storage reservoir comprising a porous medium, wherein the presence of a solid porous medium prevents the substantial collapse of said reservoir if, for example, the pressure inside the reservoir is less than the pressure outside, or adjacent to, or surrounding, or at the same elevation as said reservoir. For example, some embodiments may employ a storage reservoir comprising a porous medium, wherein the presence of a solid porous medium prevents the substantial collapse of said reservoir if, for example, a fluid is pumped out of or removed from a storage reservoir at a greater volumetric rate than fluid is added to or pumped into a storage reservoir. For example, some embodiments may employ a storage reservoir comprising a porous medium, wherein the presence of a solid porous medium prevents the substantial collapse of said reservoir if, for example, a fluid is pumped out of or removed from a storage reservoir without the simultaneous additional of another fluid to said reservoir. Substantial collapse may comprise a storage reservoir decreasing in total volume by greater than or equal to, one or more or a combination of the following: 1 percent, or 5 percent,

or 10 percent, or 15 percent, or 20 percent, or 25 percent, or 30 percent, or 35 percent, or 40 percent, or 45 percent, or 50 percent, or 55 percent, or 60 percent, or 65 percent, or 70 percent, or 75 percent, or 80 percent, or 85 percent, or 90 percent, or 95 percent

Example Advantages:

- Cost:
 - Material cost is low. Material cost may simply comprise a liner, pipes, filling material (if not already available in the surrounding environment), and pneumatic generator or pump
 - Labor cost may vary depending on whether the installation is part of another project, such as the construction of a marine structure, and whether the installation required digging beneath the surface of the ground or dredging.
- Resilience and durability:
 - Some embodiments may be located underground or beneath the surface of a water body, reducing potential hazards from waves and debris
 - Some embodiments may have no moving parts beneath the surface of the water body, reducing or eliminating potential complications from corrosion, fouling, or debris
 - Moving parts may, if desired, not be in contact or direct contact with water or the water body, reducing their cost and increasing their expected lifespan
- Efficiency
 - Pneumatic generators powered using relatively low pressure pressurized air can produce electricity at an efficiency greater than 50%, or greater than 60%, or greater than 70%, or greater than 80%, or greater than 90%.

Example Step by Step Descriptions

Underground Air & Water Cavity:

[0689] Overview: Figures 14 – 19 may show embodiments employing an underground storage region or cavity, which may be employed for generating energy from tides and / or storing energy in the gravitational potential energy of displacing a high density fluid with a low density fluid. Some figures may show an example step in a process of generating electricity from changes in water level due to, for example, including, but not limited to, tides. In Figures 14-19, the storage region or cavity may comprise mostly open space for fluid, such as air, or a low density liquid, or water, or a high density liquid, or any combination thereof, to occupy.

[0690] **Figure 14:** Step 1 (Higher Tide, Filling, Electricity Generation): Figure 14 may show an embodiment where electricity is being generated. Air is allowed to be released through the opening of a valve in the air tube or pneumatic pump, which allows air to exit storage region through a pipe into a pneumatic generator, which may generate electricity. Due to the relatively high water level in the surrounding or nearby water body relative to the water level in the storage region, the air pressure in the storage region may be greater than the atmosphere air pressure. Water from the surrounding or nearby water body may pass through a pump or travel via seepage into the storage region, displacing the air in said storage region. The flow rate of air exiting the storage region and the rate of water entering the storage region may be controlled by controlling the flow rate of air entering the pneumatic generator.

[0691] **Figure 15:** Step 2 (High Tide, Cavity Full): Figure 15 may show an embodiment where the storage region is nearly full with water. The storage region may be considered nearly full with water when it achieves either of the following: 1) the water level in the storage region is near or at the maximum water level in the nearby water body's recent tide range; or 2) the water volume reaches the maximum practical volumetric capacity of the storage region.

[0692] **Figure 16:** Step 3 (Lower Tide, Emptying, Generating Electricity): Figure 16 may show an embodiment generating electricity when the surrounding water body water level is relatively low compared to the water level inside the storage region. Energy may be generated due to the flow of air into the storage region as water exits said storage region, and where said flow of air powers, for example, a pneumatic generator. The flow of water out of said storage region may be through a water pipe or water seepage. It is important to note depth of the storage region or, if a water pipe is connected to the storage region, the depth of the water pipe, may desirably be lower than the depth of the water in water body to prevent uncontrolled water exiting or air entering the storage region. Air flow and water exiting may be controlled through the opening of a valve in connected to the air tube or pneumatic generator.

[0693] **Figure 17:** Step 4 (Lower Tide, Empty): Figure 17 may show an embodiment where the storage region is nearly empty with water. The storage region may be considered nearly empty with water when it achieves one of the following: 1) the water level in the storage region is near or at the minimum water level in the nearby water body's recent tide range; or 2) there is no water in the storage region.

[0694] **Figure 18:** Step 4 Alternative (Lower Tide, Empty, depending on time of year and location): Figure 18 may show an embodiment where the storage region is fully empty with water. It is important to note that energy generation from water exiting a storage region may require the

water pipe or the storage region to be at least partially beneath the surface of the water to prevent unintentional air or water flow. It is important to note that a storage region occupied almost entirely by air may maximize the potential energy generation capacity.

[0695] Figure 19: Step 5 (Lower Tide, Pump remaining water out): Figure 19 may show an embodiment where air or other low density fluid is pumped into a storage region to displace water. It may be desirable to pump air or another lower density fluid into the storage region, for example, while the water level or tide of the surrounding water body is relatively low, or while electricity or power is in excess or relatively inexpensive, or any combination thereof. In some embodiments, the energy required to pump air into the storage region (and displacing residual water) at a lower tide may be significantly less than the energy generated from the increase in displaceable volume occupied by air in the storage region. In some embodiments, the energy required to pump air or other low density fluid to displace water may be equal to or greater than the amount of energy generated by water displacing the air or other low density fluid. The present embodiment may comprise an energy storage process. The present embodiment may comprise an energy storage system, wherein the presence of tides or tidal power may improve the round trip energy efficiency and / or enable the generation of more electricity than the electricity required during charging or storage. Additionally, air or other low density fluid may be pumped into the storage region to remove water which may have been trapped in the air pipe.

Example embodiment where water / air cavity or storage region contains a porous material:

[0696] Overview: Figures 20 – 23 may show embodiments employing an underground storage region or cavity. Each figure may show an example step in the process of generating electricity from changes in water level due to, for example, including, but not limited to, tides. In Figures 14-19, the storage region or cavity may comprise mostly porous filling material, which may contain space for fluid, such as air or water, to occupy. The steps for generating electricity may be similar to the steps shown in Figures 14-19.

[0697] Figure 20: Step 1 (Higher Tide, Filling, Electricity Generation): Figure 20 shows an example embodiment where water / air cavity or storage region contains a porous material.

[0698] Figure 21: Step 2 (High Tide, Cavity Full): Figure 21 shows an example embodiment where water / air cavity or storage region contains a porous material.

[0699] Figure 22: Step 3 (Lower Tide, Emptying, Generating Electricity): Figure 22 shows an example embodiment where water / air cavity or storage region contains a porous material.

[0700] Figure 23: Step 4 (Lower Tide, Empty): Figure 23 shows an example embodiment where water air cavity or storage region contains a porous material.

Under Water Vessel (may be near Full Head Height throughout Power Generation, may comprise an simultaneous energy storage system and tidal power system):

[0701] **Figure 24:** Step 1 (Higher Tide, Filling, Generating Electricity): Figure 24 shows an example embodiment where water / air cavity or storage region is located on or within a water body.

[0702] **Figure 25:** Step 2 (Higher Tide, Full): Figure 25 shows an example embodiment where water / air cavity or storage region is located on or within a water body.

[0703] **Figure 26:** Step 3 (Lower Tide, Emptying): Figure 26 shows an example embodiment where water / air cavity or storage region is located on or within a water body.

[0704] **Figure 27:** Alternative Step 3 (Lower Tide, Emptying, Depending on Tide and Location): Figure 27 shows an example embodiment where water / air cavity or storage region is located on or within a water body.

[0705] **Figure 28:** Step 4 (Lower Tide, Empty): Figure 28 shows an example embodiment where water / air cavity or storage region is located on or within a water body.

[0706] **Figure 29:** Figure 29 shows an example embodiment with a floating pump or generator station.

[0707] It will be appreciated that while many of the above figures show the vessel or other storage structure at or near the bottom of the water body, it may be located at any convenient location below the surface. In some embodiments it may be moored to the bottom and/or the top of the water body.

[0708] Air may be substituted with other fluids described herein. In the case where the fluid comprises a liquid, a hydraulic or hydroelectric generator may be employed instead of a pneumatic generator.

[0709] Relatively higher tides are when the water level in a water body is higher than the water level during relatively lower tides. Water level changes may be due to primarily changes in the water level due to gravitational tides.

EXAMPLE EXEMPLARY EMBODIMENTS:

- A tidal power system comprising:
 - A region comprising a cavity, or concave region, or a storage region surrounded by at least a portion water impermeable material
 - Wherein water displaces air from said region at relatively high tides,
 - Wherein air displaces water at relatively lower tides
 - Wherein electricity is generated from movement of air to or from said region

EXAMPLE EXAMPLARY SUB-EMBODIMENTS:

- Wherein energy or electricity is generated using a pneumatic turbine or generator
- Wherein said region is located beneath the surface of the ground, or inside a causeway, or a landfill, or an artificial island, or a breakwall, or a building foundation, or a structure foundation, or a combination thereof
- Wherein said storage region contains a porous fill material
- Wherein said porous fill material comprises one or more or a combination of the following: sand, gravel, rock, packing material, or cinderblock, or plastic bottles, or plastic containers, or plastic buckets, or interconnected cinderblock, or interconnected plastic containers, or interconnected packing material
- Wherein said water impermeable material may comprise a liner
- Wherein air exits and enters said region using a pipe
- Wherein said pipe has an opening inside said storage region or an opening above the surface of the water or both
- Wherein water enters or exits said region via water seepage
- Wherein water enters or exits said region via a pipe
- Wherein water enters or exits said region through an opening in said region or water impermeable material
- Wherein said is structurally rigid
- Wherein said region is structurally flexible or expandable or collapsible and may comprise a bladder, bag, or similar device
- Wherein said air is located inside said structurally flexible region and said structurally flexible region is inflated during lower tides and collapsed during higher tides
- Wherein said collapsing generates electricity through the displacement of air from said structurally flexible region into a pneumatic generator
- Wherein said region comprises infrastructure employed for another purpose, such as one or more or a combination of the following: a sewer system, a drainage system, a runoff water system, a wastewater system, a drainage pipe, an intake pipe, an intake system, an outflow pipe, an outflow system, or a storage region.
- Wherein a liner comprises one or more or a combination of the following: a HDPE liner, or LDPE liner, or aluminum liner, or steel liner, or metal coated liner, or metal liner, or cement liner, a cement layer, or clay liner, or landfill liner, or pond liner, or lake liner, storage basin liner, or a nylon liner, or geosynthetic liner, or PVC liner, or bag, or fabric,

or textile, or mesh, or high strength polymer liner, or woven liner, or braided liner, or liner comprising multiple layers of materials for strength and fluid tightness, or tarp.

- Wherein said region is constructed as an aspect of an artificial reef or from vessels or structures which may otherwise be sunk or a combination thereof
- Wherein air is pumped into said region during lower tides and air is released from said region into a generator during higher tides
- Wherein the energy generated during higher tides exceeds the energy consumed during lower tides
- Wherein air is pumped into said region to store electricity
- Wherein air is released from said region to generate electricity
- Wherein the present invention can function as a tidal power energy generation device, an energy storage device, or both

Cold Water Power Generation

[0710] The lower density fluid and / or higher density fluid may be at a lower temperature, or higher temperature, or different temperature than the ambient air temperature, or air temperature at the water surface, or the temperature of the water at one or more depths, or any combination thereof. For example, lower density fluid and / or higher density fluid, when being transferred from the lower elevation reservoir to the higher elevation reservoir, may be at a temperature less than the surface water temperature, or surface air temperature, or both in, for example, a water body with a thermocline. For example, in some embodiments wherein the system is located in a thermocline water body, the energy storage system may be designed such that at least a portion of heat is removed from the low density fluid and/or high density fluid when transferred to, or stored in, or transferred from, or any combination thereof the lower elevation reservoir. For example, in some embodiments wherein the system is located in a thermocline water body, the energy storage system may be designed such that at least a portion of heat is removed from the low density fluid and/or high density fluid by heat exchange with the ocean water or water body when transferred to, or stored in, or transferred from, or any combination thereof the lower elevation reservoir.

[0711] In some embodiments wherein the system is located in a thermocline water body, low density fluid and / or high density fluid, which may be at a temperature different than the surface water temperature or surface air temperature, may be employed in a heat engine to generate power.

[0712] For example, in some embodiments wherein the system is located in a thermocline water body, the low density fluid and / or high density fluid may be at a lower temperature than the surface air temperature or surface water temperature when said low density fluid and / or high

density fluid are transferred from the lower elevation reservoir to the higher elevation reservoir. Said lower temperature low density fluid and / or high density fluid may be employed for the cold side or heat sink of a heat engine. For example, said low temperature low density fluid and / or high density fluid may be heat exchanged with a working fluid in the heat engine such that heat is transferred from the working fluid in the heat engine to the lower temperature low density fluid and / or high density fluid. The hot side of said heat engine may comprise a heat source, which may include, but is not limited to, air, or air on the surface, or water, or surface water, or an application requiring cooling, or waste heat, or condenser water, or any combination thereof.

[0713] The heat engine may comprise one or more or a combination of heat engines, which may include, but are not limited to, rankine cycles, or the organic rankine cycle, or kalina cycle, or open cycles, or closed cycles, or air turbines, or stirring motors, or heat engines for generating power from small temperature differences, or osmotic heat engines, or any combination thereof.

[0714] A thermocline water body may comprise a water body wherein the temperature of the water changes with depth. For example, a thermocline water body may comprise an ocean connected water body, or ocean, or a lake, or other water body wherein the temperature of the water near the surface of the water body is greater than the temperature of the water near the bottom of the water body.

[0715] In some embodiments, it may be desirable to employ a low density fluid and / or high density fluid with an enhanced specific heat capacity. For example, some embodiments may employ a fluid with a specific heat capacity greater than water. For example, some embodiments may employ a fluid with a specific heat capacity greater than glycol antifreeze. For example, some embodiments may employ a fluid-fluid phase transition fluid with an enthalpy of fluid-fluid phase transition which may result in an effective specific heat capacity greater than the specific heat capacity of the individual chemicals which comprise said fluid-fluid phase transition fluid in a desired temperature range. Enhanced specific heat capacity may enable greater power generation and / or total heat transfer and / or thermal storage per a cubic meter of low density fluid and / or high density fluid. Enhanced specific heat capacity may enable greater power generation and / or total heat transfer and / or thermal storage per a cubic meter of low density fluid and / or high density fluid, in, for example, embodiments which employ the low density fluid and / or high density fluid as a heat source, or heat sink, or enthalpy source.

[0716] Some embodiments of the present invention may comprise a closed system. For example, in some embodiments, the low density fluid and / or high density fluid may not be in direct contact with air or water in the external environment in normal operation of the system. In

some embodiments, the low density fluid and / or high density fluid being in a closed system may be advantageous because it may prevent, or minimize potential biofouling, or scaling, or corrosion, or any combination thereof. In some embodiments, the low density fluid and / or high density fluid being in a closed system may be advantageous because it may prevent, or minimize potential biofouling, or scaling, or corrosion, or any combination thereof, which may increase the longevity and / or long term efficiency and / or reduce the capital cost of an ocean thermal energy conversion system, or system for generating energy from a difference in temperature, or any combination thereof employing the low density fluid and / or high density fluid.

[0717] In some embodiments, a subsea heat exchanger, or heat exchange process, or any combination thereof to facilitate the heat exchange with deep water or removal of heat from the low density fluid and / or high density fluid. In some embodiments, said heat exchange may involve the pipes, or risers, or storage vessels, or any combination thereof employed in the system or in the lower elevation reservoir. In some embodiments, said heat exchange may involve or further involve a subsea heat exchanger, or heat exchange coil, or any combination thereof to facilitate heat transfer between the low density fluid and / or high density fluid and the deep water, or facilitate heat removal from the low density fluid and / or high density fluid or any combination thereof.

[0718] In some embodiments, it may be desirable to generate power from the temperature difference between a low density fluid and / or high density fluid and another medium when, for example, power is needed. For example, power may be generated from the heat engine instead of, or in addition to, generating power from the displacement of a low density fluid with a high density fluid. For example, power may be generated from the heat engine instead of, or in addition to, generating power from discharging the energy storage system.

[0719] For example, the below table shows the estimated kWh of power generated from 1 cubic meter of a low density fluid and / or high density fluid with the following specific heat capacities and densities at 50% of Carnot efficiency with a 45F cold side and 85F hot side. As shown below, depending on the density and specific heat capacity, the amount of power generated per m3 of low density fluid and / or high density fluid may be significant relative to the energy stored or generated from the displacement of water with a low density fluid. In some instances, the amount of power generated from the temperature difference between the low density fluid and / or high density fluid and a heat source may be greater than the amount of energy stored from fluid displacement energy storage. In some embodiments, the energy storage system may comprise a simultaneous heat engine, and, uniquely, may generate more power than is stored.

[0720]

Density of fluid (tonnes/m ³) (Right)	2.5	2.25	1.75	1.5	1.25	1	0.9	0.8	0.7	0.6	0.5
Specific Heat Capacity (MJ/tonne deg C)(Down)											
8	5.14	4.63	3.60	3.08	2.57	2.06	1.85	1.65	1.44	1.23	1.03
7.5	4.82	4.34	3.37	2.89	2.41	1.93	1.73	1.54	1.35	1.16	0.96
7	4.50	4.05	3.15	2.70	2.25	1.80	1.62	1.44	1.26	1.08	0.90
6.5	4.18	3.76	2.92	2.51	2.09	1.67	1.50	1.34	1.17	1.00	0.84
6	3.86	3.47	2.70	2.31	1.93	1.54	1.39	1.23	1.08	0.93	0.77
5.5	3.53	3.18	2.47	2.12	1.77	1.41	1.27	1.13	0.99	0.85	0.71
5	3.21	2.89	2.25	1.93	1.61	1.29	1.16	1.03	0.90	0.77	0.64
4.5	2.89	2.60	2.02	1.73	1.45	1.16	1.04	0.93	0.81	0.69	0.58
4	2.57	2.31	1.80	1.54	1.29	1.03	0.93	0.82	0.72	0.62	0.51
3.5	2.25	2.02	1.57	1.35	1.12	0.90	0.81	0.72	0.63	0.54	0.45
3	1.93	1.73	1.35	1.16	0.96	0.77	0.69	0.62	0.54	0.46	0.39
2.5	1.61	1.45	1.12	0.96	0.80	0.64	0.58	0.51	0.45	0.39	0.32
2	1.29	1.16	0.90	0.77	0.64	0.51	0.46	0.41	0.36	0.31	0.26

SPECIFIC EMBODIMENTS

[0721] Embodiments for “Systems and Methods for Preventing Fouling of Marine Structures”

1. A system for reducing fouling on an aquatic structure comprising:
an aquatic structure comprising at least one surface exposed to water;
a concave region on at least one portion of the surface exposed to water wherein said concave region is configured to maintain a substantially non-contiguous physical separation between water and said region and wherein at least a portion of said concave region is occupied with a gas.
2. The system of Embodiment 1 wherein the substantially non-contiguous physical separation is maintained by controlling the amount of gas in said concave region.
3. The system of Embodiment 1 further comprising a controller and a gas source operably connected to said concave region wherein the controller and gas source control the amount of gas.

4. The system of Embodiment 3 wherein said controller and gas source are employed to displace water with gas in at least a portion of said concave region.
5. The system of Embodiment 1 wherein the said gas pocket is controllably immobilized for a controlled period of time.
6. The system of Embodiment 5 wherein said time is at least about 5 seconds.
7. The system of Embodiment 1 wherein said substantially non-contiguous physical separation is present greater than 30% of the time said structure is in use.
8. A system for reducing fouling on an aquatic structure comprising:
an aquatic structure comprising at least one surface exposed to water when the structure is in use;
a concave region on at least one portion of the surface exposed to water wherein said concave region is configured to maintain a substantially non-contiguous physical separation between water and said region.
9. The system of Embodiment 8 wherein the volume beneath said concave region is adjustable.
10. The system of Embodiment 8 wherein the surface area of the concave region is adjustable.
11. The system of Embodiment 8 wherein the height of the concave region relative to water is adjustable.
12. The system of Embodiment 8 wherein at least one of the volume beneath said concave region, the surface area of the concave region, or the height of the concave region above water, is adjusted by changing the surface morphology of or on the concave region.
13. The system of Embodiment 8 wherein at least a portion of the surface exposed to water is substantially hydrophobic.
14. An improved aquatic structure comprising:
a structure comprising at least one surface exposed to water when the structure is in use wherein the improvement comprises:
configuring at least a portion of said surface exposed to water such that said portion has a non-contiguous separation with water when the structure is in use and wherein the portion having a non-contiguous separation with water provides a gas pocket between said portion and water when the structure is in use.
15. The improved aquatic structure of Embodiment 14 wherein the amount of substantially non-contiguous physical separation with water of the surface exposed to water is controlled by adjusting the amount of gas in the pocket.

16. The improved aquatic structure of Embodiment 14 wherein said non-contiguous separation is present greater than 30% of the time said structure is in use.
17. The improved aquatic structure of Embodiment 14 wherein said portion configured to be non-contiguous reduces visible fouling by at least 50% as compared to a similar structure lacking said non-contiguous portion.
18. The improved aquatic structure of Embodiment 14 wherein the amount of gas in the pocket is adjustable.
19. The improved aquatic structure of Embodiment 14 wherein the volume of the gas pocket is adjustable.
20. The improved aquatic structure of Embodiment 14 wherein the surface area or volume of the non-contiguous separated portion is adjustable.
21. The system of Embodiment 14 wherein the height of the non-contiguous separated portion with respect to water is adjustable.

[0722] Embodiments for “Low Density Fluid Displacement to Generate Power”

1. A system for generating electricity comprising:
a first storage reservoir near the surface of a body of water and configured to store a low density fluid which is substantially immiscible with water;
a second storage reservoir located below the surface of a body of water and configured to store water; a pump; and
a generator;
wherein the pump, generator, and the first and second reservoir are operatively connected such that electricity is stored by displacing water in the second storage reservoir by pumping low density fluid in the first storage reservoir to the second storage reservoir and electricity is generated (or discharge) by allowing the low density fluid in the second storage reservoir to return to the first reservoir.
2. The system of Embodiment 1 wherein the pump and the generator may be the same unit.
3. The system of Embodiment 1 wherein said second storage reservoir comprises an expandable or contractible structure.
4. The system of Embodiment 1 wherein said second storage reservoir comprises a bladder, a bag, or a balloon.
5. The system of Embodiment 1 wherein said second storage reservoir contains a concave region with an opening near the bottom of said concave region open to the body of water.

6. The system of Embodiment 1 wherein said second storage reservoir is tethered to the bottom of said water body.
 7. The system of Embodiment 1 wherein the low density fluid comprises a hydrocarbon liquid or natural gas.
 8. The system of Embodiment 1 wherein the low density fluid comprises compressed natural gas or liquid natural gas.
 9. The system of Embodiment 1 which is operatively connected to a unit requiring electricity.
 10. A process to generate energy comprising:
storing energy by displacing at least a portion of a first fluid having a first density with a second fluid having a second density which is lower than said first fluid wherein said first and second fluid are substantially immiscible in each other;
allowing a power discharge by displacing at least a portion of the lower density second fluid with the first higher density fluid;
wherein said generating step, allowing step, or both are facilitated by pressure and gravity.
 11. The process of Embodiment 10 wherein said generating step, allowing step, or both occur beneath a surface of water wherein said water is employed to facilitate pressure.
 12. The process of Embodiment 10 wherein said first fluid is water.
 13. The process of Embodiment 10 wherein said second fluid comprises compressed natural gas, liquid natural gas, liquid hydrocarbon, petroleum ether, or crude oil.
 14. The process of Embodiment 10 wherein the second fluid having a second density is stored near the surface of a body of water.
 15. The process of Embodiment 10 which further comprises converting the power discharge to electricity.
 16. The process of Embodiment 10 which further comprises storing said power discharge.
 17. The process of Embodiment 10 which further comprises converting the power discharge to electricity.
 18. The process of Embodiment 10 wherein the first or second fluid comprise a waste fluid.
 19. The process of Embodiment 10 wherein the first or second fluid comprise a fluid generated from a solid waste.
 20. The process of Embodiment 10 wherein the first or second fluid comprise a cooking oil.
- [0723]** Embodiments for “Underwater Energy Storage and Electricity”
1. A process for generating electricity from tides comprising:

providing a cavity which is operatively linked to tidal waters and configured such that air is displaced with water at higher tides and such that water is displaced with air at lower tides;

displacing at least a portion of air within the cavity with water at higher tides;

displacing at least a portion of water within the cavity with air at lower tides;

wherein the displacing of water, air or both generates power.

2. The process of Embodiment 1 wherein the cavity is open on bottom.
3. The process of Embodiment 1 further comprising transferring at least a portion of displaced air to a pneumatic generator.
4. The process of Embodiment 1 which further comprises controlling the flow rate of air during displacing of air.
5. The process of Embodiment 1 which further comprises controlling the flow rate of water during displacing of air.
6. The process of Embodiment 1 wherein the cavity is above ground.
7. The process of Embodiment 1 wherein the cavity is below ground.
8. The process of Embodiment 1 wherein the cavity is at least partially submerged in a tidal water body.
9. The process of Embodiment 1 further comprising transferring at least a portion of displaced air to a pneumatic generator through one or more pipes.
10. The process of Embodiment 1 wherein the cavity comprises a flexible liner.
11. The process of Embodiment 1 wherein the cavity is rigid.
12. The process of Embodiment 1 wherein the cavity is expandable or collapsible.
13. The process of Embodiment 1 which is configured such that power generated at higher tides exceeds any power consumed during lower tides.
14. A process for generating electricity from tides comprising:

providing a cavity which is at least partially filled with a porous material and air which cavity is operatively linked to tidal waters and configured such that air is displaced with water at higher tides and such that water is displaced with air at lower tides;

displacing at least a portion of air within the cavity with water at higher tides;

displacing at least a portion of water within the cavity with air at lower tides;

wherein the displacing of water, air or both generates power.
15. The process of Embodiment 14 wherein the porous material comprises sand, gravel, rock, packing material, or cinderblock, or plastic bottles, or plastic containers, or plastic buckets, or

interconnected cinderblock, or interconnected plastic containers, interconnected packing material, or mixtures thereof.

16. The process of Embodiment 14 wherein the cavity comprises a flexible liner.
17. The process of Embodiment 14 wherein the cavity is rigid.
18. The process of Embodiment 14 wherein the cavity is expandable or collapsible.
19. The process of Embodiment 14 further comprising transferring at least a portion of displaced air to a pneumatic generator.
20. The process of Embodiment 14 which further comprises controlling the flow rate of water during displacing of air.

[0724] Additional Embodiments

1. A system for storing and generating power comprising:
 - a first storage reservoir near the surface of a body of water and configured to store a first fluid;
 - a second storage reservoir located below the surface of the body of water and configured to store a second fluid which has a higher density than the first fluid;
 - a pump; and
 - a generator;wherein the pump, generator, and the first and second reservoir are operatively connected such that power is stored by displacing the second fluid which has a higher density than the first fluid in the second storage reservoir by pumping the first fluid in the first storage reservoir to the second storage reservoir and power is generated or discharged by allowing the first fluid in the second storage reservoir to return to the first storage reservoir; and
 - wherein the first fluid is a liquid.
2. The system of embodiment 1 further comprising third reservoir configured to store the second fluid.
3. The system of embodiment 1 wherein the elevation of the first reservoir is above the elevation of the second reservoir.
4. The system of embodiment 2 wherein the third reservoir is at substantially the same elevation as the first reservoir.
5. The system of embodiment 2 wherein said third reservoir is substantially at the same elevation as the second reservoir.
6. The system of embodiment 2 wherein the elevation of the third reservoir is above the elevation of the first reservoir

7. The system of embodiment 2 wherein the second fluid is displaced from the second reservoir during storing of power is transferred to and stored in said third reservoir.
8. The system of embodiment 1 wherein said second fluid comprises brine, or reverse osmosis discharge brine, or sodium chloride, or sea salt, or calcium chloride, or magnesium chloride, or potassium formate, or magnesium sulfate, or calcium bromide, or sodium bromide, or potassium acetate, or sodium formate, or calcium nitrate, or sodium nitrate, or sodium sulfite, or potassium sulfite, or sodium bisulfite, or potassium bisulfite, or magnesium sulfite, or magnesium bisulfite, or calcium bisulfite, or corn syrup, or glycerin, or propylene glycol, or ethylene glycol, or propylene carbonate, or any combination thereof.
9. The system of embodiment 1 wherein said second fluid comprises a halogenated hydrocarbon, or a fluorocarbon, or an organic acid, or an inorganic acid, or carbon dioxide, or sulfur dioxide, or a nitrogen oxide, or any combination thereof.
10. The system of embodiment 1 wherein said first fluid comprises a hydrocarbon.
11. The system of embodiment 1 wherein said first fluid comprises air.
12. The system of embodiment 1 wherein the density of said second fluid is greater than 1.02 kilograms per liter at 20°C.
13. The system of embodiment 1 wherein said first fluid comprises water.
14. The system of embodiment 1 wherein the pressure inside the second reservoir and the pressure of the adjacent body of water differ by from about 0 bar to about 10 bar.
15. The system of embodiment 1 further comprising a pressure exchanger.
16. The system of embodiment 15 wherein said pressure exchanger is located near the second reservoir.
17. The system of embodiment 15 wherein during storing of power, the pressure exchanger extracts pressure from the first fluid and transfers the extracted pressure to the second fluid.
18. The system of embodiment 15 wherein during generating of power, the pressure exchanger extracts pressure from the second fluid and transfers the extracted pressure to the first fluid.
19. The system of embodiment 17 wherein said pressure extraction occurs (1) while the first fluid is being transferred to the second reservoir or (2) prior to transfer or (3) both (1) and (2).
20. The system of embodiment 18 wherein said pressure extraction occurs (1) while the second fluid is being transferred to the second reservoir or (2) prior to transfer or (3) both (1) and (2).
21. The system of embodiment 17 wherein the pressure exchanger extracts pressure less than or equal to the pressure of the first fluid near the second reservoir minus the hydrostatic pressure of the body of water at the elevation of the second reservoir.

22. The system of embodiment 18 wherein the pressure exchanger extracts pressure less than or equal to the pressure of the second fluid near the second reservoir minus the hydrostatic pressure of the body of water at the elevation of the second reservoir.
23. The system of embodiment 15 wherein the pressure exchanger enables the use of the second fluid while enabling the second reservoir to be at pressure equilibrium with the body of water at the same elevation as the second reservoir.
24. The system of embodiment 15 wherein the pressure exchanger comprises a hydraulic pressure exchanger.
25. The system of embodiment 15 wherein the pressure exchanger adjusts pressure extraction to ensure the pressure of fluid inside the second reservoir differs from the hydrostatic pressure of the body of water at the same elevation as the second reservoir by less than a tolerance pressure.
26. The system of embodiment 25 wherein the second reservoir contains an internal pressure sensor and an external pressure sensor;
wherein the internal pressure sensor measures the pressure of fluids inside the second reservoir; and
wherein the external pressure sensor measures the pressure of the body of water adjacent to the second reservoir; and
wherein the internal pressure sensor and the external pressure sensor are configured to communicate with the pressure exchanger.
27. The system of embodiment 25 wherein said tolerance pressure is less than about 10 atm.
28. The system of embodiment 25 wherein said tolerance pressure is less than 200 atmospheres.
29. The system of embodiment 15 wherein the pressure exchanger is a pump, or turbine, or rotary turbine, or any combination thereof.
30. A process for storing and generating power comprising:
operatively connecting a pump, a generator, a first storage reservoir near the surface of a body of water, and a second storage reservoir located below the surface of the body of water; wherein the first storage reservoir is configured to store a first fluid and wherein the second storage reservoir is configured to store a second fluid which has a higher density than the first fluid;
storing power by displacing the second fluid in the second storage reservoir by pumping the first fluid in the first storage reservoir to the second storage reservoir; and
generating or discharging power by allowing the first fluid in the second storage reservoir to return to the first storage reservoir;

wherein the second fluid is incompressible.

What is claimed is:

1. A system for storing and generating power comprising:
 - a first storage reservoir near the surface of a body of water and configured to store a first fluid;
 - a second storage reservoir located below the surface of the body of water and configured to store a second fluid which has a higher density than the first fluid;
 - a pump; and
 - a generator;
 - wherein the pump, generator, and the first and second reservoir are operatively connected such that power is stored by displacing the second fluid which has a higher density than the first fluid in the second storage reservoir by pumping the first fluid in the first storage reservoir to the second storage reservoir and power is generated or discharged by allowing the first fluid in the second storage reservoir to return to the first storage reservoir; and
 - wherein the first fluid is a liquid.
2. The system of claim 1 wherein the elevation of the first reservoir is above the elevation of the second reservoir.
3. The system of claim 1 further comprising a third reservoir configured to store the second fluid.
4. The system of claim 3 wherein the third reservoir is at substantially the same elevation as the first reservoir.
5. The system of claim 3 wherein the elevation of the third reservoir is above the elevation of the first reservoir.
6. The system of claim 3 wherein the second fluid displaced from the second reservoir during storing of power is transferred to and stored in said third reservoir.
7. The system of claim 1 wherein said second fluid comprises brine, or reverse osmosis discharge brine, or sodium chloride, or sea salt, or calcium chloride, or magnesium chloride, or potassium formate, or magnesium sulfate, or calcium bromide, or sodium bromide, or potassium acetate, or sodium formate, or calcium nitrate, or sodium nitrate, or sodium sulfite, or potassium sulfite, or sodium bisulfite, or potassium bisulfite, or magnesium sulfite, or magnesium bisulfite, or calcium bisulfite, or corn syrup, or glycerin, or propylene glycol, or ethylene glycol, or propylene carbonate, or halogenated hydrocarbon, or halogen, or a fluorocarbon, or an organic acid, or an inorganic acid, or carbon dioxide, or sulfur dioxide, or a nitrogen oxide, or any combination thereof.

8. The system of claim 1 wherein said first fluid is selected from a hydrocarbon, or water, or ammonia.
9. The system of claim 1 further comprising a pressure exchanger.
10. The system of claim 9 wherein said pressure exchanger is located near the second reservoir.
11. The system of claim 9 wherein during storing of power, the pressure exchanger extracts pressure from the first fluid and transfers the extracted pressure to the second fluid.
12. The system of claim 9 wherein during generating of power, the pressure exchanger extracts pressure from the second fluid and transfers the extracted pressure to the first fluid.
13. The system of claim 9 wherein the pressure exchanger adjusts pressure extraction to ensure the pressure of fluid inside the second reservoir differs from the hydrostatic pressure of the body of water at the same elevation as the second reservoir by less than a tolerance pressure.
14. The system of claim 13 wherein the second reservoir contains an internal pressure sensor and an external pressure sensor;
 - wherein the internal pressure sensor measures the pressure of fluids inside the second reservoir; and
 - wherein the external pressure sensor measures the pressure of the body of water adjacent to the second reservoir; and
 - wherein the internal pressure sensor and the external pressure sensor are configured to communicate with the pressure exchanger.
15. A process for storing and generating power comprising:
 - operatively connecting a pump, a generator, a first storage reservoir near the surface of a body of water, and a second storage reservoir located below the surface of the body of water; wherein the first storage reservoir is configured to store a first fluid and wherein the second storage reservoir is configured to store a second fluid which has a higher density than the first fluid;
 - storing power by displacing the second fluid in the second storage reservoir by pumping the first fluid in the first storage reservoir to the second storage reservoir; and
 - generating or discharging power by allowing the first fluid in the second storage reservoir to return to the first storage reservoir;
 - wherein the first fluid is a liquid.