VERY LARGE SCALE DECARBONIZATION

Permanent CO_2 Sequestration in Shale Reservoirs
Restored to their Pre-Production State

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Shale reservoirs are present everywhere in the world and many are immensely rich in natural gas or methane (CH_4)

These shale rocks can be many times more adsorptive of carbon dioxide (CO_2) than the natural gas / methane within them

If we could convert the methane from these shales into CO_2 vie electric power generation, then there would remain behind in the rock profoundly greater capacity to store massive amounts of atmospheric CO_2 ... far greater than the amount of CO_2 produced from the methane in power generation

Thus, ironically, shale gas reservoirs pose the greatest opportunity for humankind to sequester CO_2 at the scale needed to reverse global warming

Here is how this could be accomplished…

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The first step in this process consists in stimulating the source rock and accessing the reservoir via a new extraction technology *which uses no water and no chemical additives*. The two components of the technology are non-toxic to human beings and are even used in human pharmacologic preparations *approved by the U.S. Food and Drug Administration* and other similar agencies / regulators around the world.

The stimulation fluids are composed of those naturally occurring in the reservoir – light weight alkanes – combined with specialized proppants (non-crystalline sand / amorphous boro-silica) which have the capacity to be dissolved by small volumes of low pH fluids at later point in time as they are essentially biodegradable substances.

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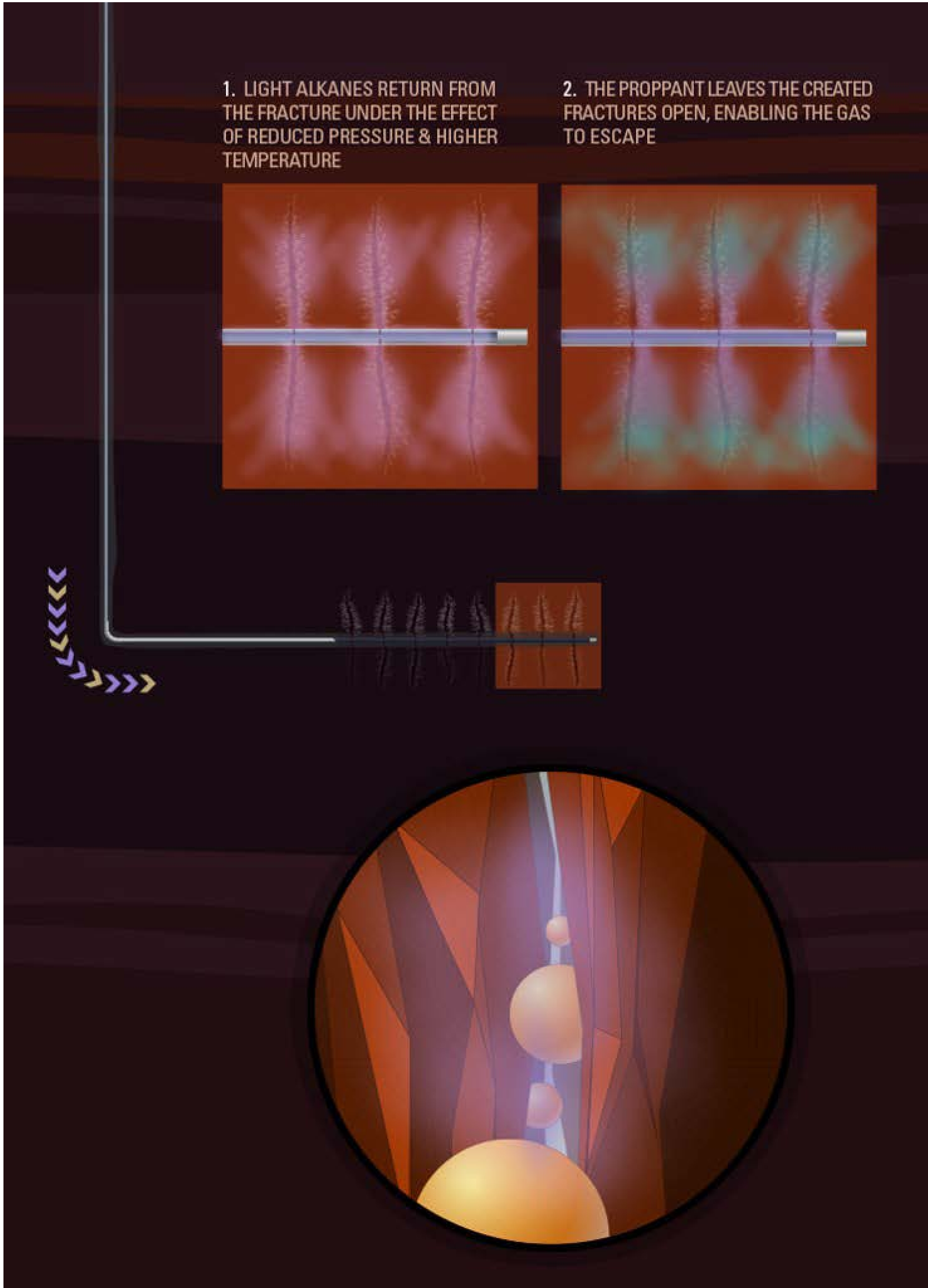
The injection of the light alkanes into the shale rock creates micro-fractures.

The specialized proppants hold the fractures open.



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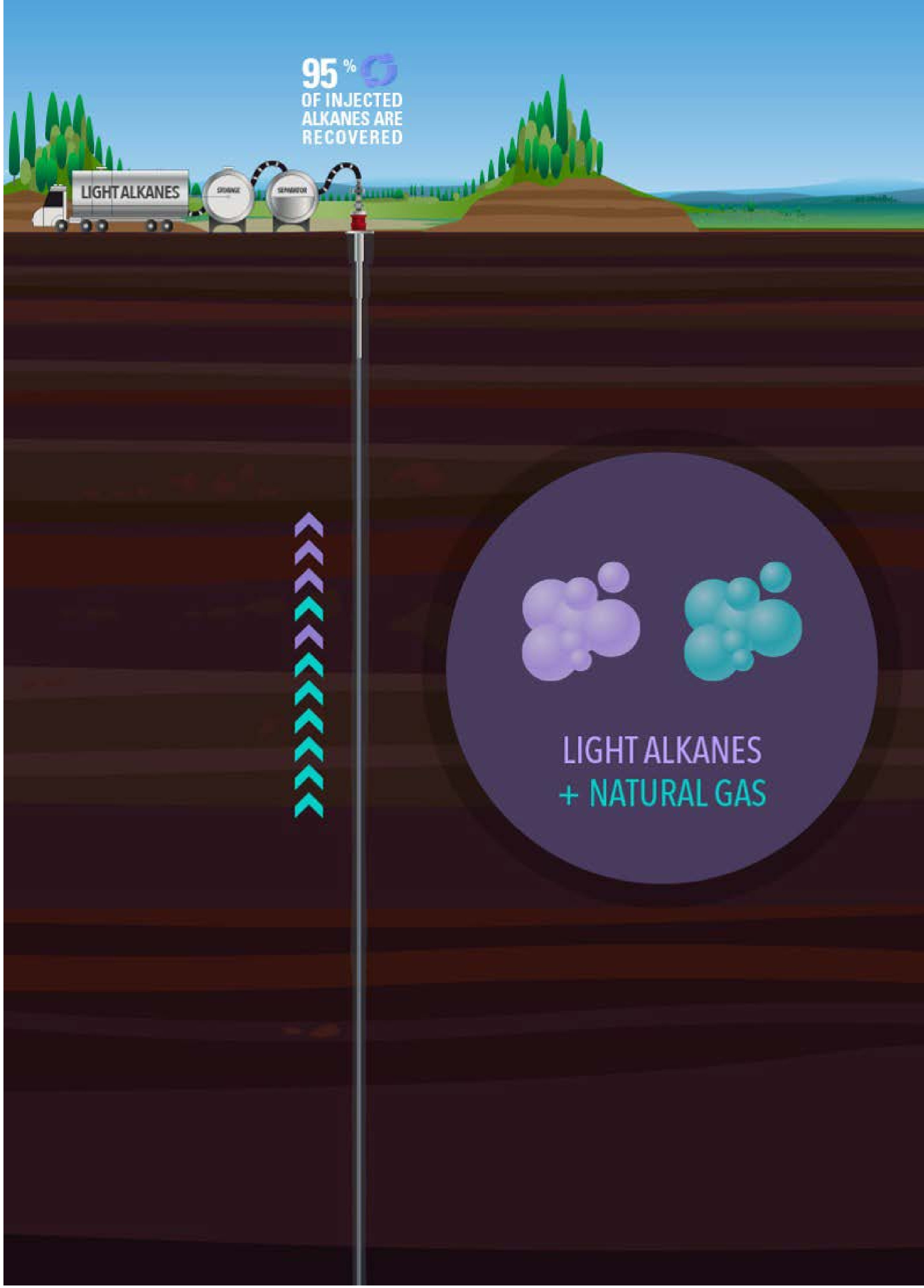
Afterwards, the light alkane stimulation fluid flows back into the well, followed by the natural gas / methane.

The returning stimulation fluid is recovered at the well head to be re-injected into the next well stimulation.



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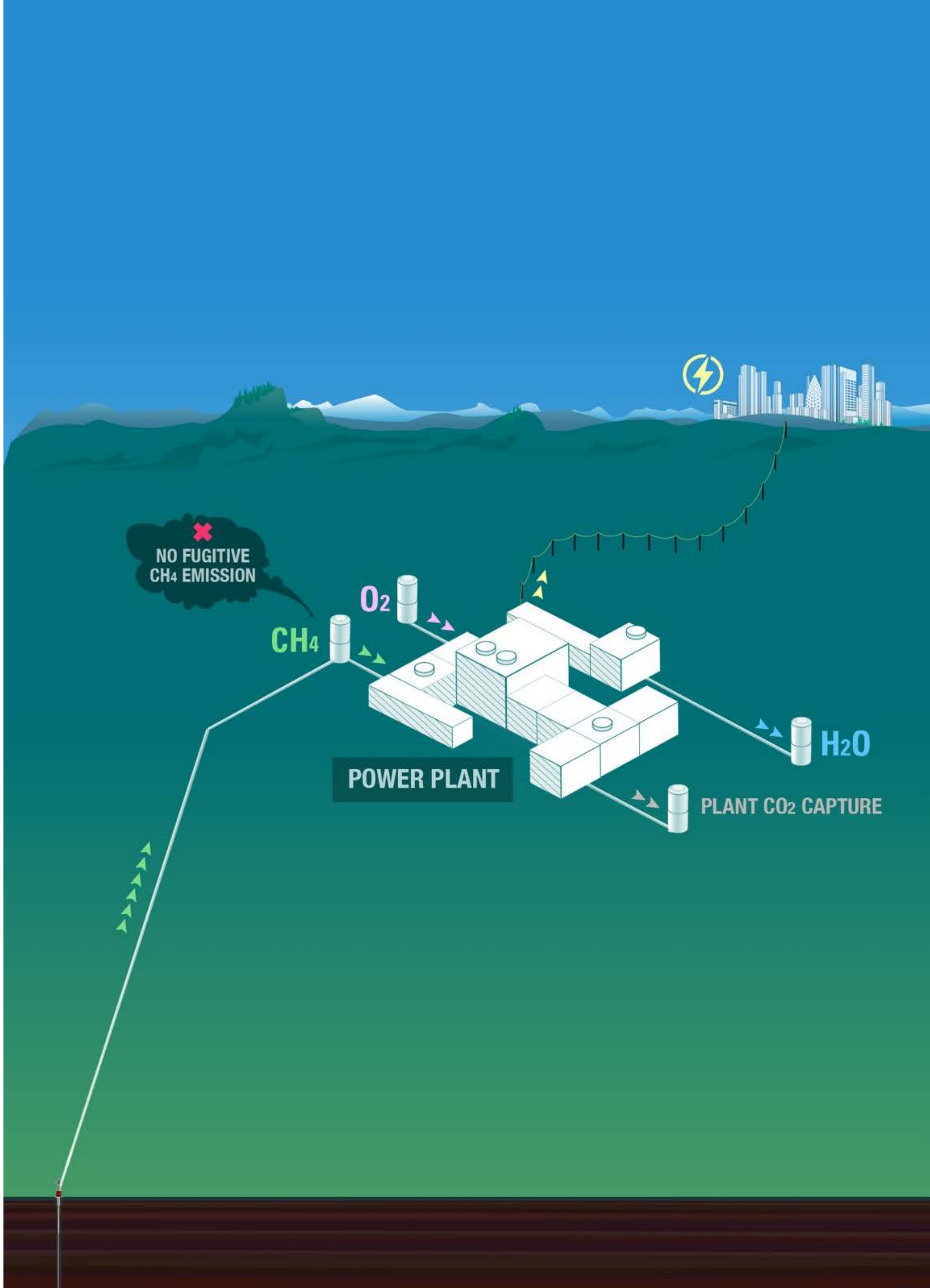
The natural gas / methane which has been extracted is used for electric power generation to (i) provide the energy to power the sequestration process, and (ii) supply surplus power when wind, wave and sun supplies are not available, such as is this case at night time for solar.

The CO_2 which is formed upon combustion of the natural gas, and when combined with bio fuels as well, in the electric generator is separated and captured to be re-injected into the shale fractures for permanent sequestration.

Large quantities of pure water (H_2O) is also formed when the natural gas is burned with pure oxygen (O_2) rather than air.



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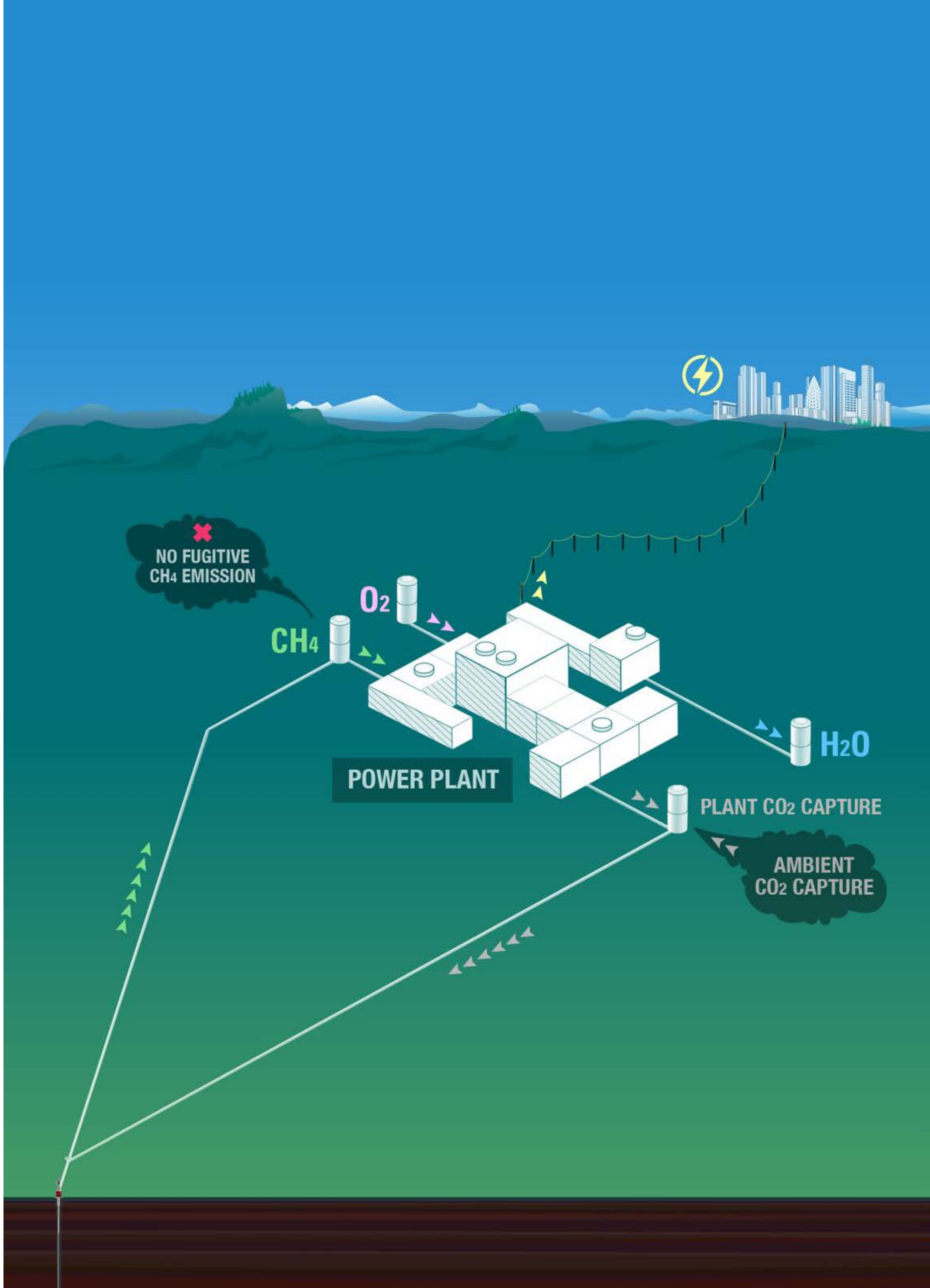
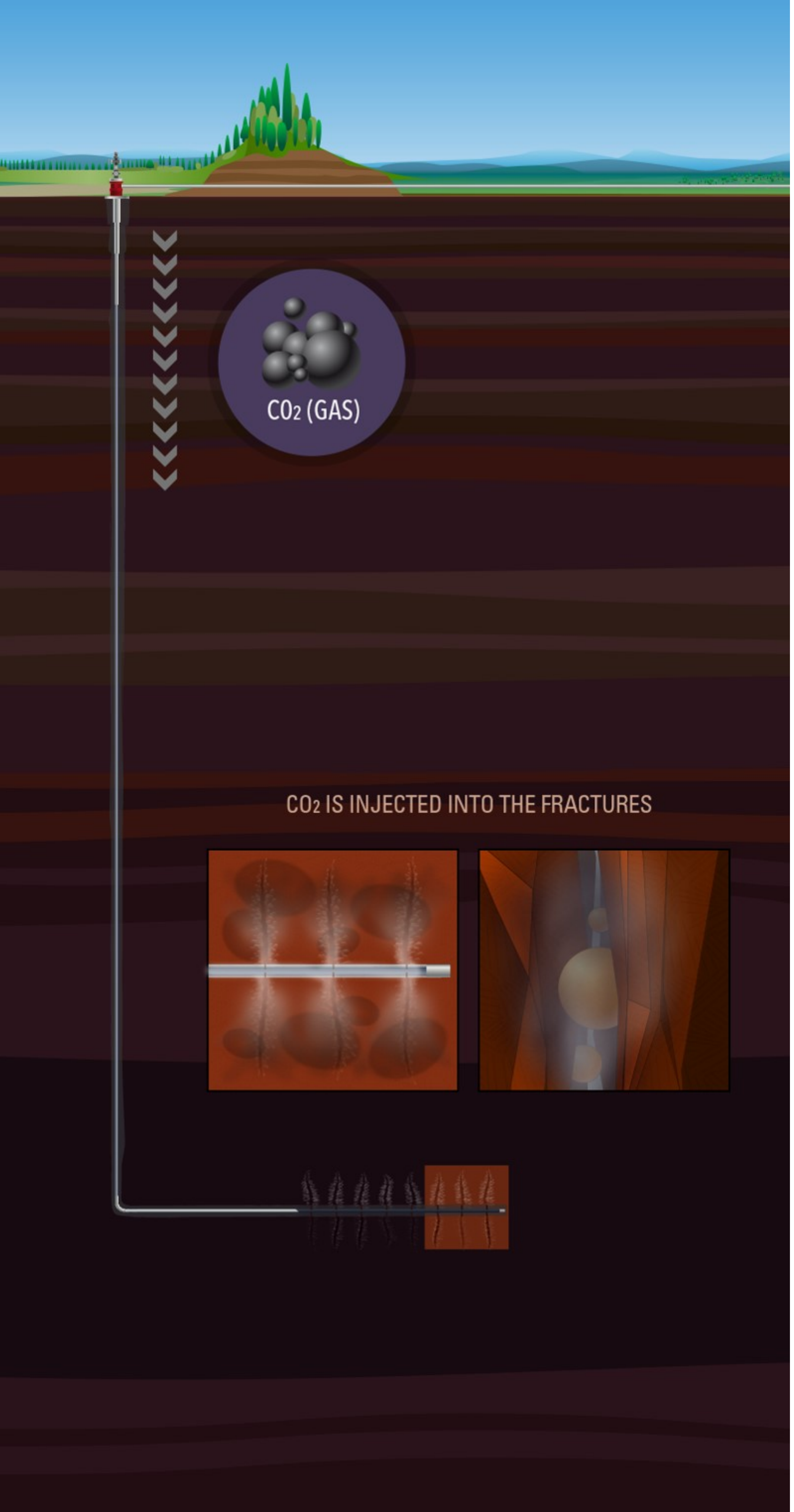
Additional ambient CO_2 captured from the atmosphere can be added to the sequestration injection stream, given the shales are many times more adsorptive of CO_2 than the original methane.

This system is particularly amenable to combination with bioenergy means of capturing carbon dioxide, wherein the resulting CO_2 from combustion of bio fuels is blended with that from direct combustion of produced methane, so-called BECCS.





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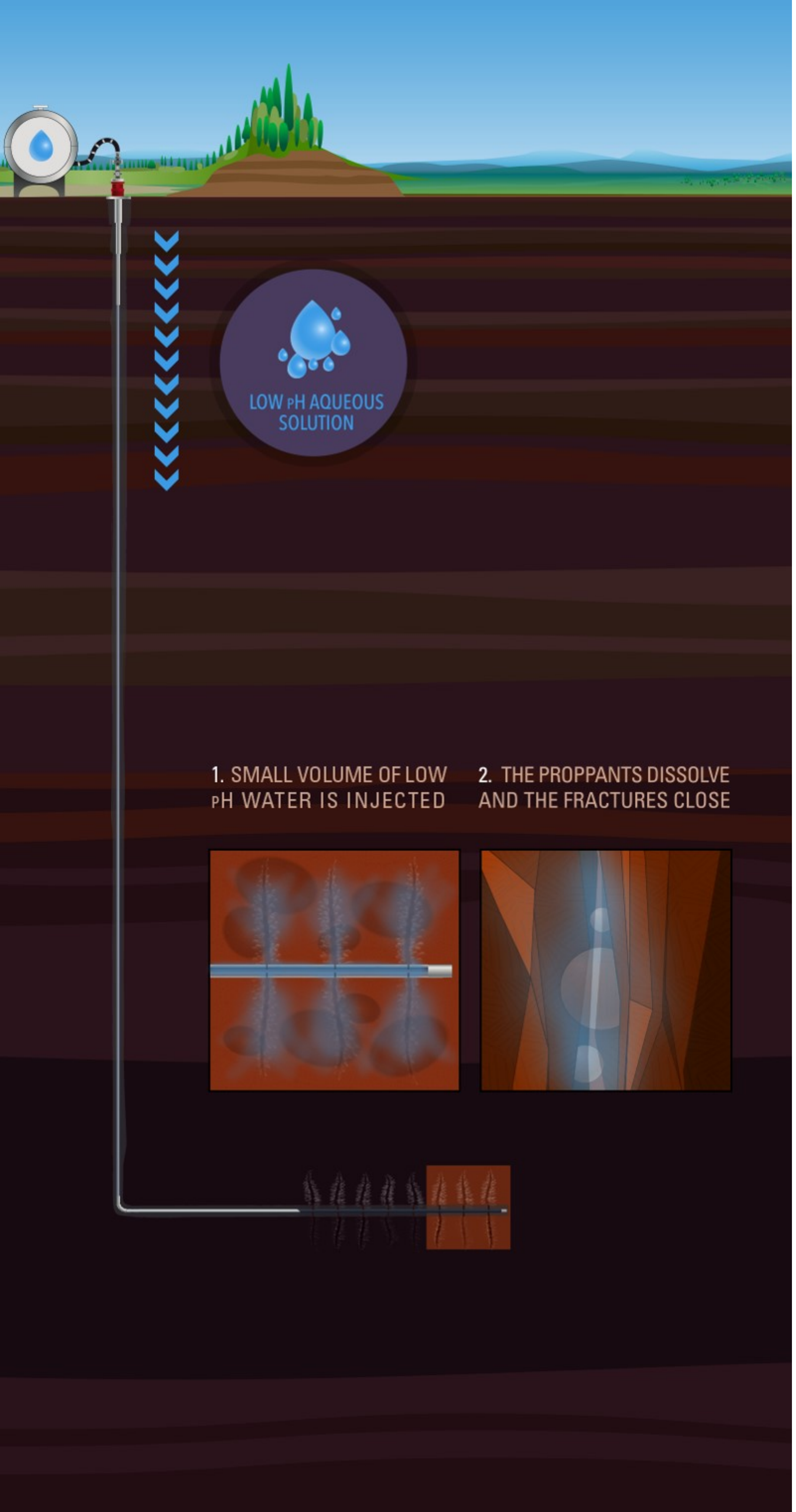
CO_2 is injected through the same fracture system and pipe that delivered the methane into power generation service in the first place.

The carbon atoms are therefore returned to their original geologic resting place via the same fractures that were created to produce the methane in the first place… a true *cradle-to-grave life cycle* for the carbon produced accompanied by a multiple of the same volume in captured atmospheric CO_2.



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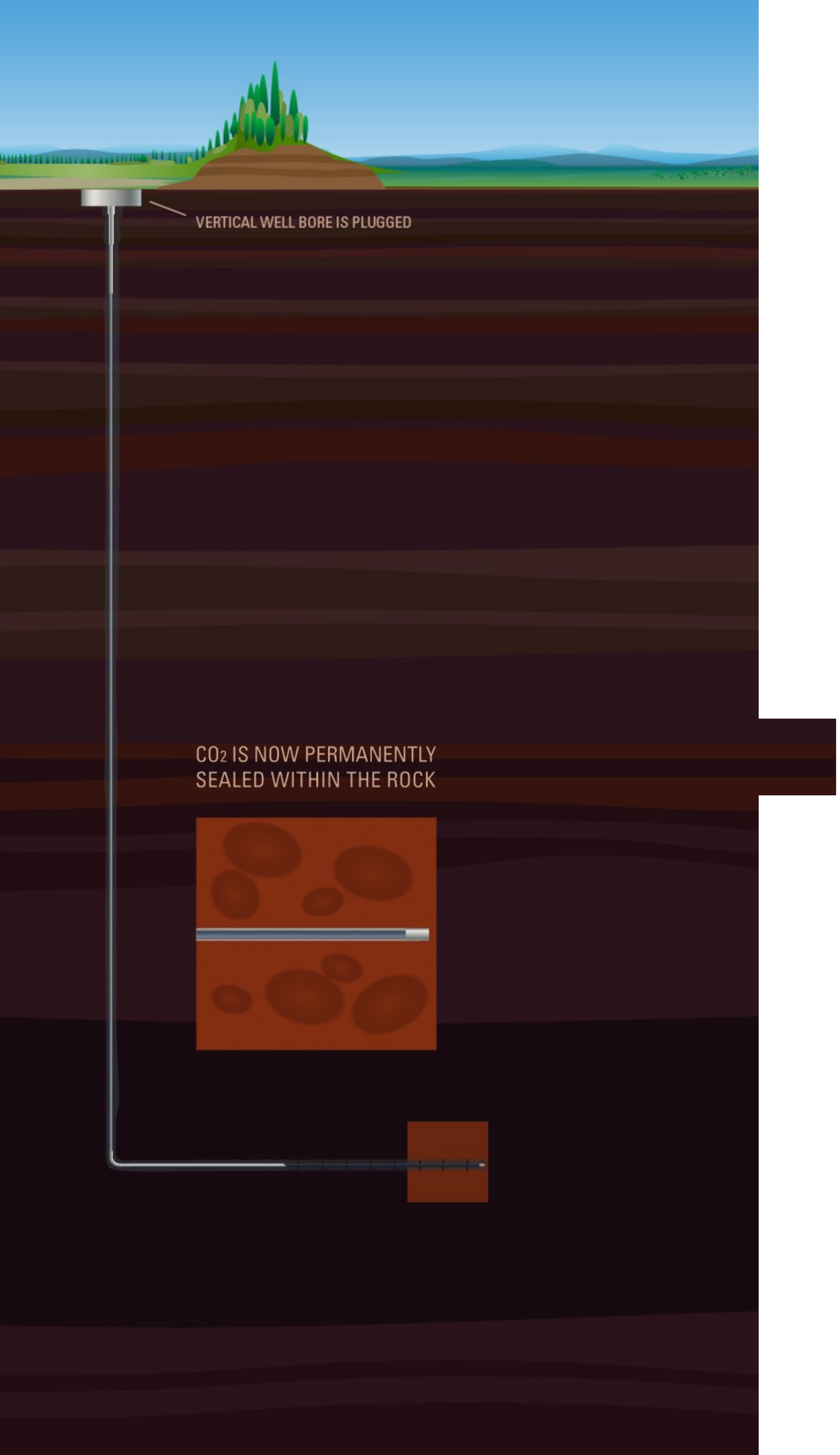
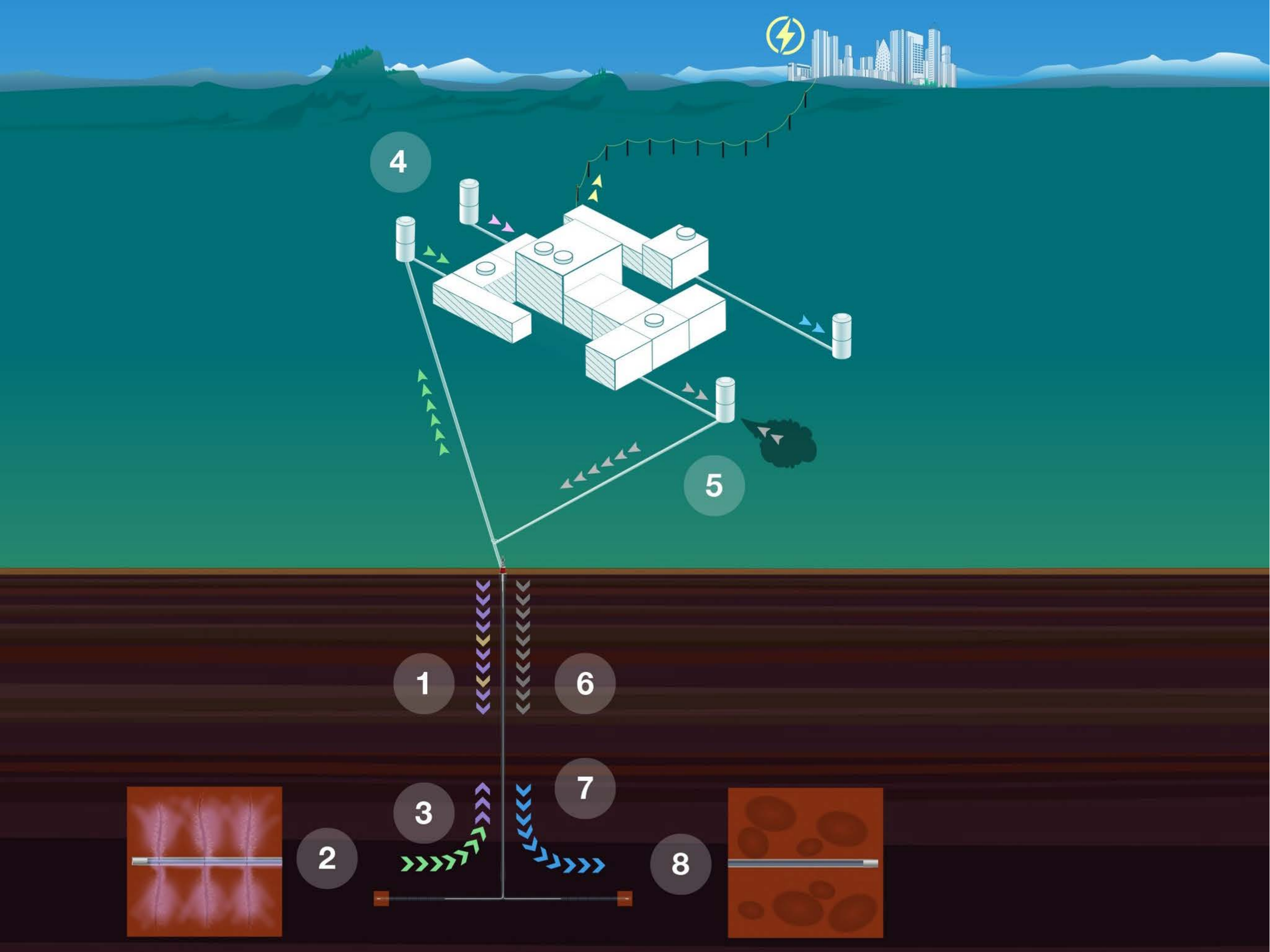
Once the shale reservoir and fracture systems are near full volumetric storage capacity with the sequestered CO_2, a small volume of a low pH solution is injected into the well bore, which dissolves the specialized amorphous boro-silica proppant that has been used during both the production and sequestration phases of the process.



The geologic forces, that were previously resisted by the proppant, now exert themselves to collapse and seal closed the fracture system, permanently trapping the CO_2 within the rock.

This seal will last throughout geologic time going forward...much longer than the cement plugged vertical well bore component of the well.



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OVERVIEW OF THE COMPONENTS OF THE PROCESS

Large cohorts of hydrocarbon productive shale wells that have been simulated by hydraulic fracturing utilizing certain select reservoir fluids suffused with specialized proppant (the particles maintaining fracture patency during production and re-injection), which can be dissolved at the end of the CO_2 sequestration cycle with a small volume of an low pH aqueous solution.

May optionally include, in certain circumstances, natural gas and / or carbon dioxide smaller scale temporary storage reservoirs or surface facilities that can facilitate the logistics of material movements and placement.

Large (combined cycle turbines) and small (peaking) electric power generating equipment.

Pre-combustion (e.g. oxy-fuel systems which provide O_2 for combustion with the natural gas) and/or post-combustion carbon dioxide capture systems (e.g., electrolytic amine, $Ca(OH)_2$, membrane, or porous carbon adsorption systems).

May most optimally include BECCS.

Extensive freshwater surface handling facilities.

VERY LARGE SCALE DE-CARBONIZATION

Temporarily accessing planetary shale source source rocks with a completely non-toxic production system, removing the natural gas (methane) within them, refilling the emptied reservoir spaces with many times more/larger volumes of atmospheric carbon dioxide, and then terminating the access pathways to these containers via natural bio-degradable means …

Permanent large scale CO_2 sequestration throughout geologic time which is not dependent upon vertical well bore durability ...

Massive surplus (net of CCS operations) power production with a profoundly negative carbon-footprint ...

Exceptional return of fresh water to the environment...

Example opportunities…

EUROPEAN SHALE CO2 SEQUESTRATION EXAMPLE

A recent study conducted by various institutions, agencies and appendages of the French Government, including IFPEN, the French Petroleum and New Energies Institute, indicates that the expected case ultimate recovery of natural gas from the SE French Basin would be 67 TCF over an approximately 20 year period from this organically rich, thick shale section. French Reports

European "base case" natural gas consumption, for which there very little utilization mitigation given its embedded nature, is approximately 400 to 500 TCF over the same twenty year time period.

The proposed shale methane extraction / CO_2 sequestration technique, if applied to the SE French Basin would likely result in 100 TCF of natural gas production from the basin (enhanced by concomitant CO_2 injections), thus supplying internally to Europe 20% of its base case needs rather than from foreign imports, but more importantly also result in sequestration of virtually all of the CO_2 generated from the 400 to 500 TCF of natural gas consumed during this same time period. Thus Europe, via this singular application, could become carbon neutral relative to its projected base case natural gas utilization through two full decades in the immediate term.

UK SHALE CO2 SEQUESTRATION EXAMPLE

Onshore UK shale in the midlands region also holds enormous shale CO_2 sequestration potential, as reported by the British Geological Society, which estimates 1000 TCF of natural gas originally in place in these basins. Again, a ten percent recovery from these source rocks, also thick and organically rich (Ref. Gainsborough Trough / British Geologic Society), could supply surplus electricity in support of the UK's avid new energy programs (sun, surf and breeze) along with a comparable CO_2 sequestration potential as could be developed in France.

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