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Artificial intelligence in Carbon Capture Utilization and Storage

What should policymakers require in the engineering of storage wells in climate change response?

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Introduction

The growing increase in the global demand for energy across industries have led to higher emissions of greenhouse gases (GHG) into the earth's atmosphere. Manufacturing factories, power plants and the vast transportation industry all use the energy derived from fossil fuels. Unfortunately, the adverse effect of the release of these gases is seen in its impact on climate change. This reality has made it important to examine strategies for addressing the impact of climate change. States and corporate bodies are now beginning to consider strategies for addressing their climate footprints. As such, various industries whose use of energy from fossil fuels impact the environment are devising means of reducing their GHG emissions.

One effective method that is gaining traction within the energy sector is the Carbon Capture Utilization and Storage (CCUS). This process broadly involves the use of techniques to contain Carbon dioxide (CO2) emissions by capturing and conveying it from its point of release for either processing, storage or permanent disposal. This process decreases the release of carbon into the atmosphere. Over the last couple of years, there is an emerging consensus that this method is important in reaching Net Zero and in the energy industry, there is growing momentum on participation in these Low Carbon Solutions (LCS) in order to reduce the impact of these emissions on the environment and on the climate. However, as the CCUS technology involves injecting carbon dioxide underground through drilled wells, it is important that these technologies are built properly and continuously efficient. In this article, I argue that the onset of artificial intelligence (AI) presents an opportunity to build intelligent underground wells for CCUS. However, there are some key areas which policy makers need to pay attention to with the use of AI in this process. In this article, I explain what this entails.

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2. The Engineering of Carbon Capture Utilization and Storage

The CCUS value chain technology is a combination of existing technologies linked together in a unique way to meet the emissions reduction objective.[2]

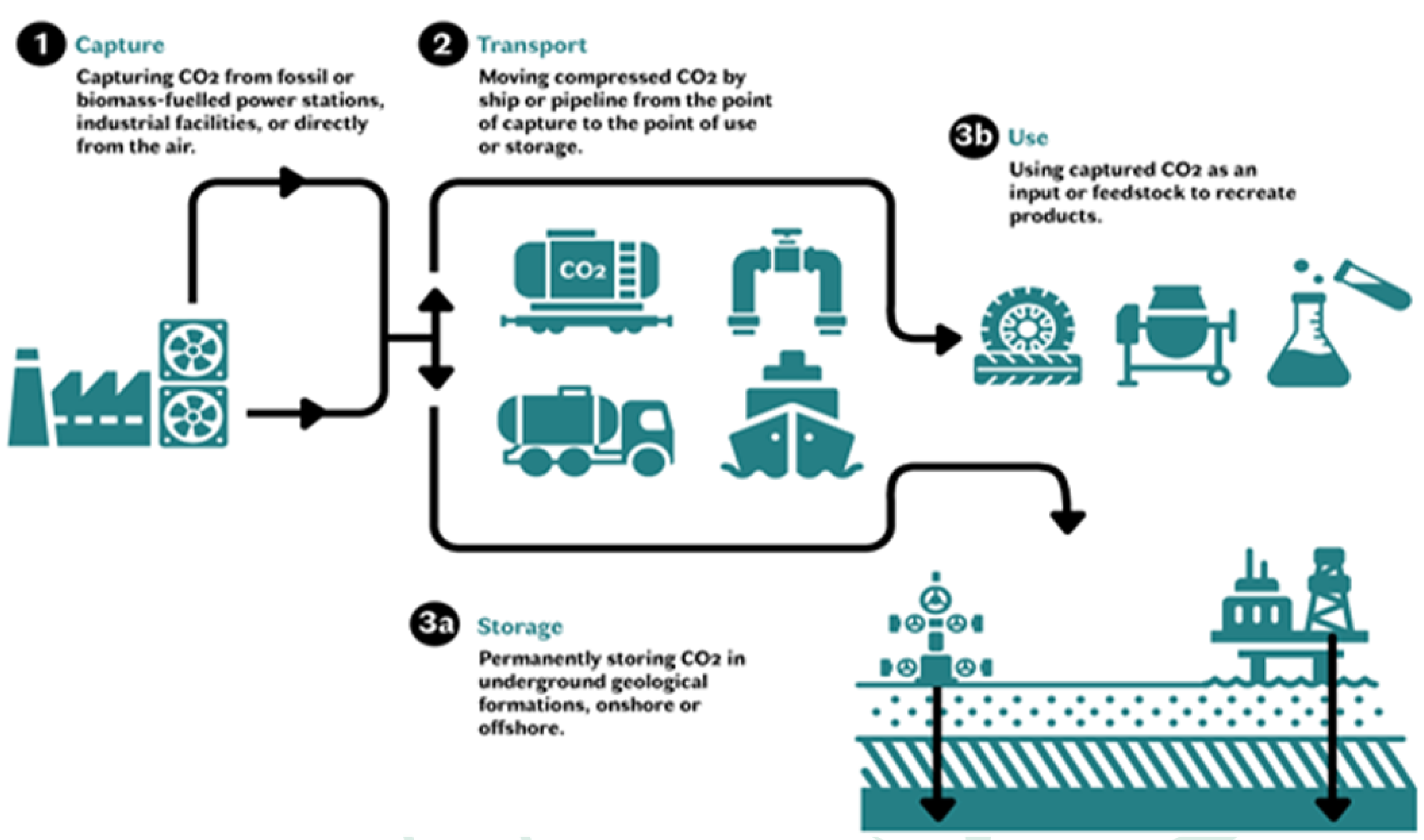


Figure 1: Flow diagram of carbon capture utilization and storage.[2]

Through this process, carbon is stored in wells underground through a process known as injection. These CCUS wells are designed to store CO2 permanently, safely and securely. The permanent disposal of CO2 by injection into underground geological formations using drilled wells constructed for this purpose has been an effective way of achieving CCUS.

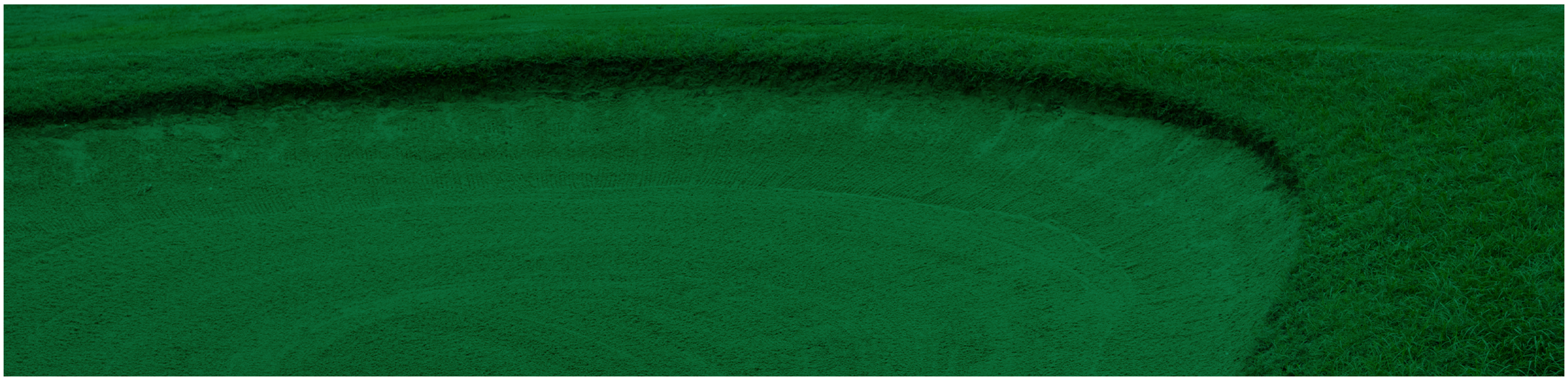
For these injection wells to function effectively, the soil/earth around these wells (known with the technical term formation) needs to be permeable and unconsolidated (i.e. a solid that allows flow of fluid or gases into and through it). This will allow for targeted injectivity rate downhole for optimum injection of the captured CO2.

However, there is a problem that usually comes with the earth (i.e. formation) being permeable and unconsolidated. This plainly is sand. Put differently, what this means is that where the soil/earth around where the wells are built are permeable, the rock material which is permeable can break apart (i.e. degrade or disintegrate) and introduce sand into the wells. As such, hindering efficient injection of the CO2.

Addressing this problem requires adopting sand control techniques which require deployment of sand control screens together with gravel packing. or In a gravel pack scenario, sand control screens are deployed downhole along with specifically sized gravel or proppants to reduce sand influx from reservoir into the wellbore during production or injection by means of filtration.

[2] Vikram Vishal, Atsumasa Sakai, Priya Prasad, José Benítez Torres, Ingvild Ombudstvedt, Richard Esposito, George Koperna, and Pamela Tomski, Carbon Capture, Utilization and Storage: Handbook for Policymakers (2024).

[3] Vikram Vishal, Atsumasa Sakai, Priya Prasad, José Benítez Torres, Ingvild Ombudstvedt, Richard Esposito, George Koperna, and Pamela Tomski, Carbon Capture, Utilization and Storage: Handbook for Policymakers (2024)



2.1 Sand Control techniques in CCUS wells engineering

Sand control techniques are well known in the process of oil and gas extraction. In oil and gas extraction, production wells are built to ensure that the oil and gas fluids extracted from the earth underground proceed from the formation to the wellbore[4] and up to the surface. In oil and gas extraction, the sand control techniques ensure that sand does not mix with the extracted product. This technique is used in the well completion process. Essentially, the concept of completing a well basically involves the installation of various equipment and tubular items into the well bore which are required for the channeling of hydrocarbon from the sub-surface reservoir to the surface in a safe, controlled, and efficient manner. In doing this, components such as valves, isolation packers and other flow control equipment are deployed downhole on a tubing string and should remain installed through the life of the well. The specifications of the equipment to be deployed such as size, pressure rating, and metallurgy are determined by the data already gathered from similar wells in the field as well as data obtained during the drilling phase of the well.

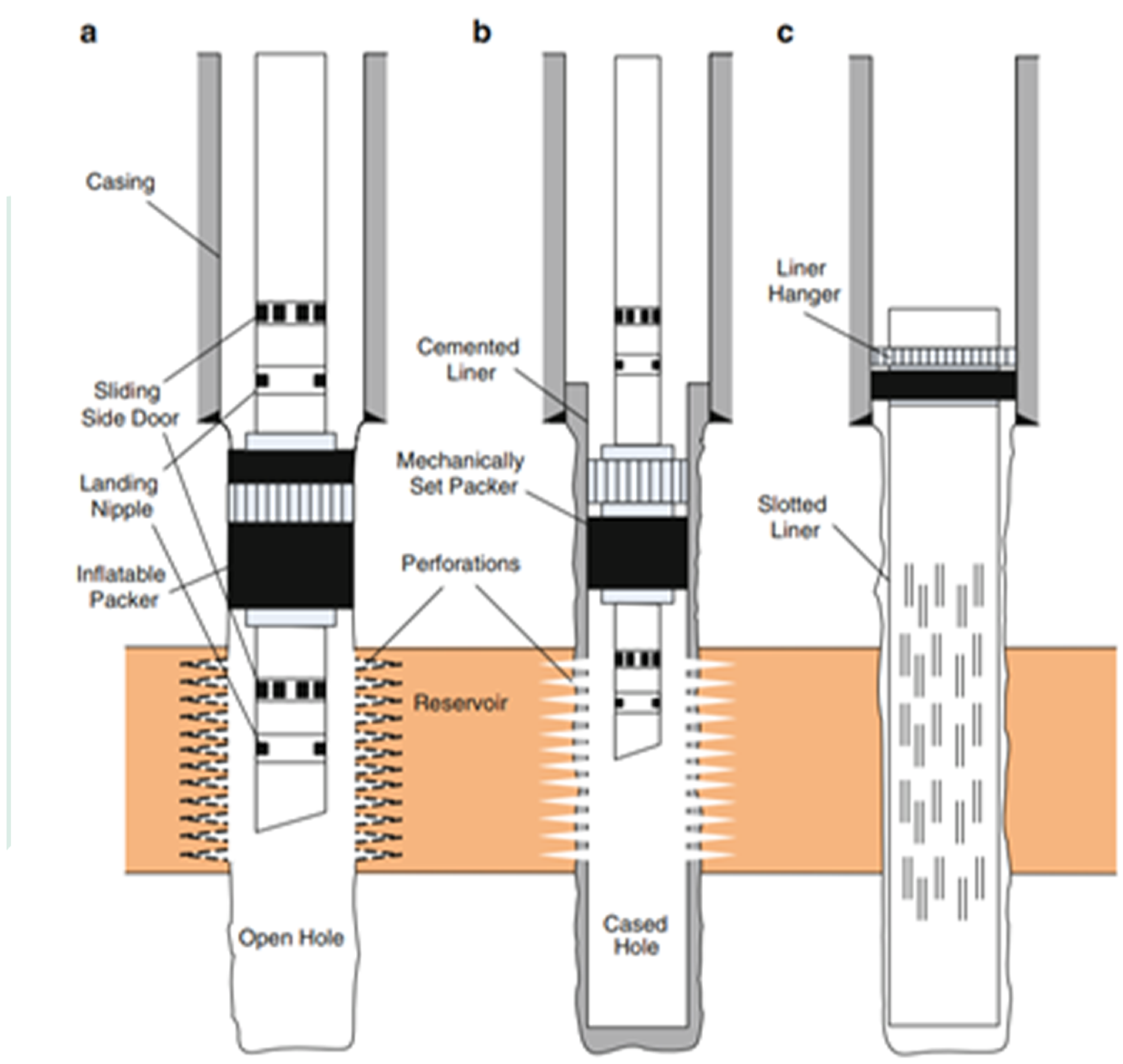
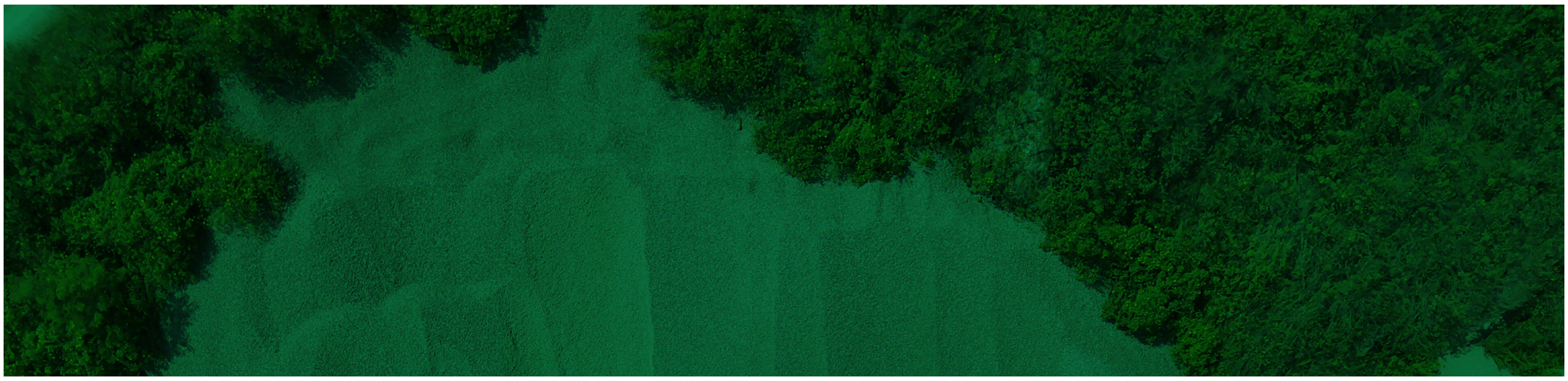


Figure 2: Basic schematic of various forms of Sand control Lower completion techniques adopted for wells: (a) Open hole completion, (b) Cased hole completion, (c)Slotted liner completion[5]

Unlike the oil and gas extraction process (which involves building production wells where reservoir fluid proceeds from the formation to the wellbore and up to the surface), wells built for CCUS are called injection wells. The CO2 is pumped downhole and pushed into the formation for storage. Sand control is important for this process to

[4] "Well bore" is basically the hole of well; it describes the part of the well that is the hole that was drilled.

[5] Davorin Matanovic, Marin Cikes and Bojan Moslavac; Sand Control in Well Construction and Operation, Springer-Verlag Berlin Heidelberg (2012)



prevent the formation particles (sands) from affecting the CCUS process. There are three important scenarios where sand-control (use of sand control screens and gravel packing) is important here that I discuss from a technical perspective:

1. During planned or unplanned shutdown of injection there can be back flows or cross flows which can mobilize formation particles back into the wellbore and perforation tunnel, this movement of formation sands back to the wellbore and perforation tunnel will cause a reduction in achievable injection when you re-start the injection. This reduction in injectivity is due to the re-arranging of the formation sand in the perforation and wellbore which lead to reduction in permeability of the formation.

2. Another adverse effect of the formation sand packing into your perforation tunnel and well bore is the significant increase in pressure drop this will cause. Studies have shown that well perforation tunnels packed with gravel pack proppants have a much lower pressure drop when compared with perforation tunnels packed with much finer formation sand [9].

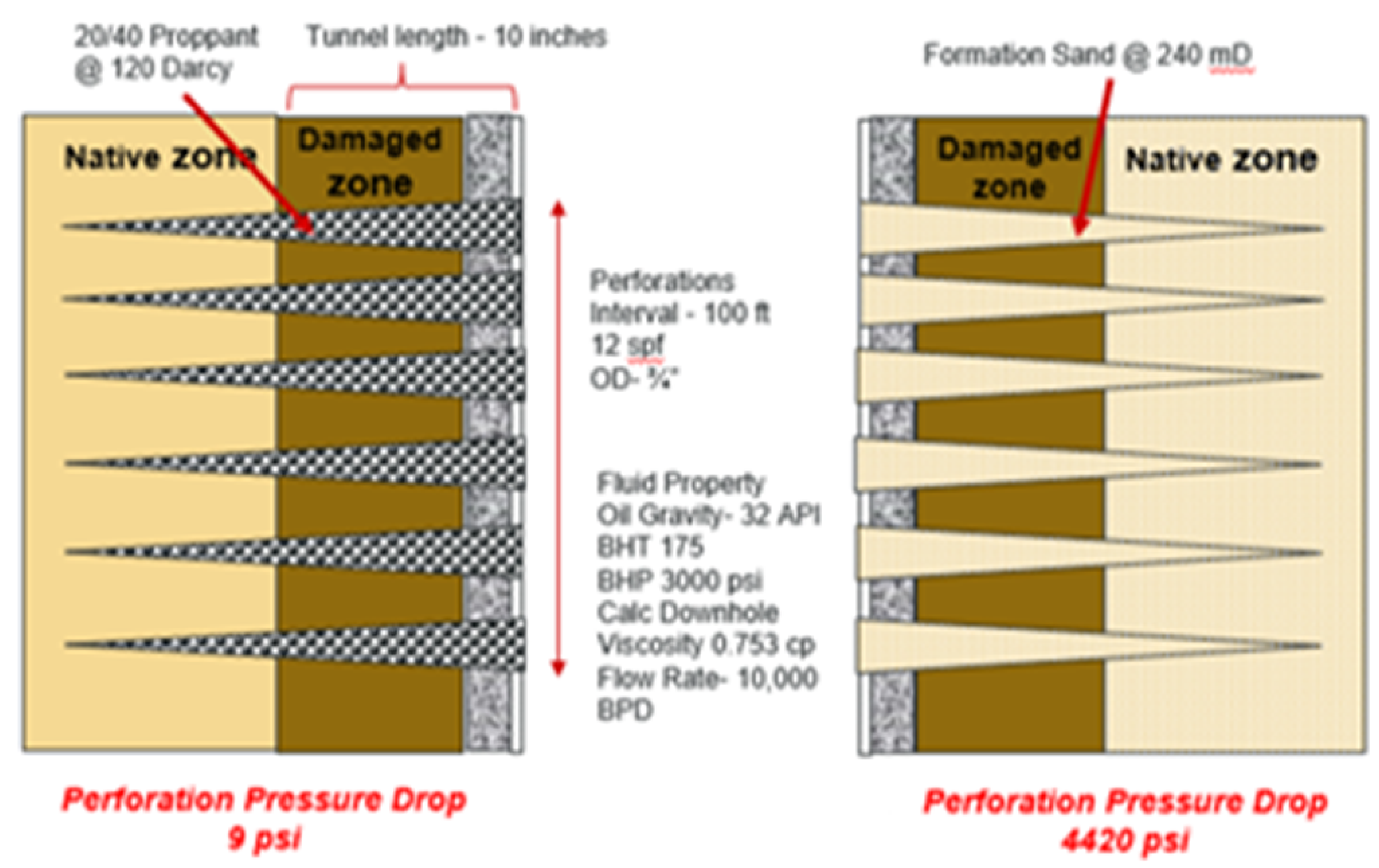


Figure 3: Diagram showing difference in pressure drop between perforation tunnels packed with proppants and that packed with formation sand[6]

3. In a well equipped with only screens, gravel pack techniques of sand control is highly recommended. This is because the formation sand introduced into the wellbore from the reservoir during shutdown, due to no gravel pack in place, may cause erosion to the screens when injection restarts. The injection pressure will jet the sands and debris back into the formation through the screen at high velocity with high risk of cutting up the screens and resulting in total loss of sand control.

[6] Morita, Nobuo, Davis, Eric, and Lee Whitebay, Guidelines for Solving Sand Problems in Water Injection Wells, Paper presented at the SPE Formation Damage Control Conference, Lafayette, Louisiana, February 1998

The use of sand control in CCUS wells have proven to be beneficial to achieving the goal of safely storing CO2 in geological formations. As such, their use in lands where the earth or formation is unconsolidated is crucial. Unconsolidated formations are prevalent for instance in Nigeria. Unconsolidated formations are prevalent for instance, in North America lands, for applications of CCUS.

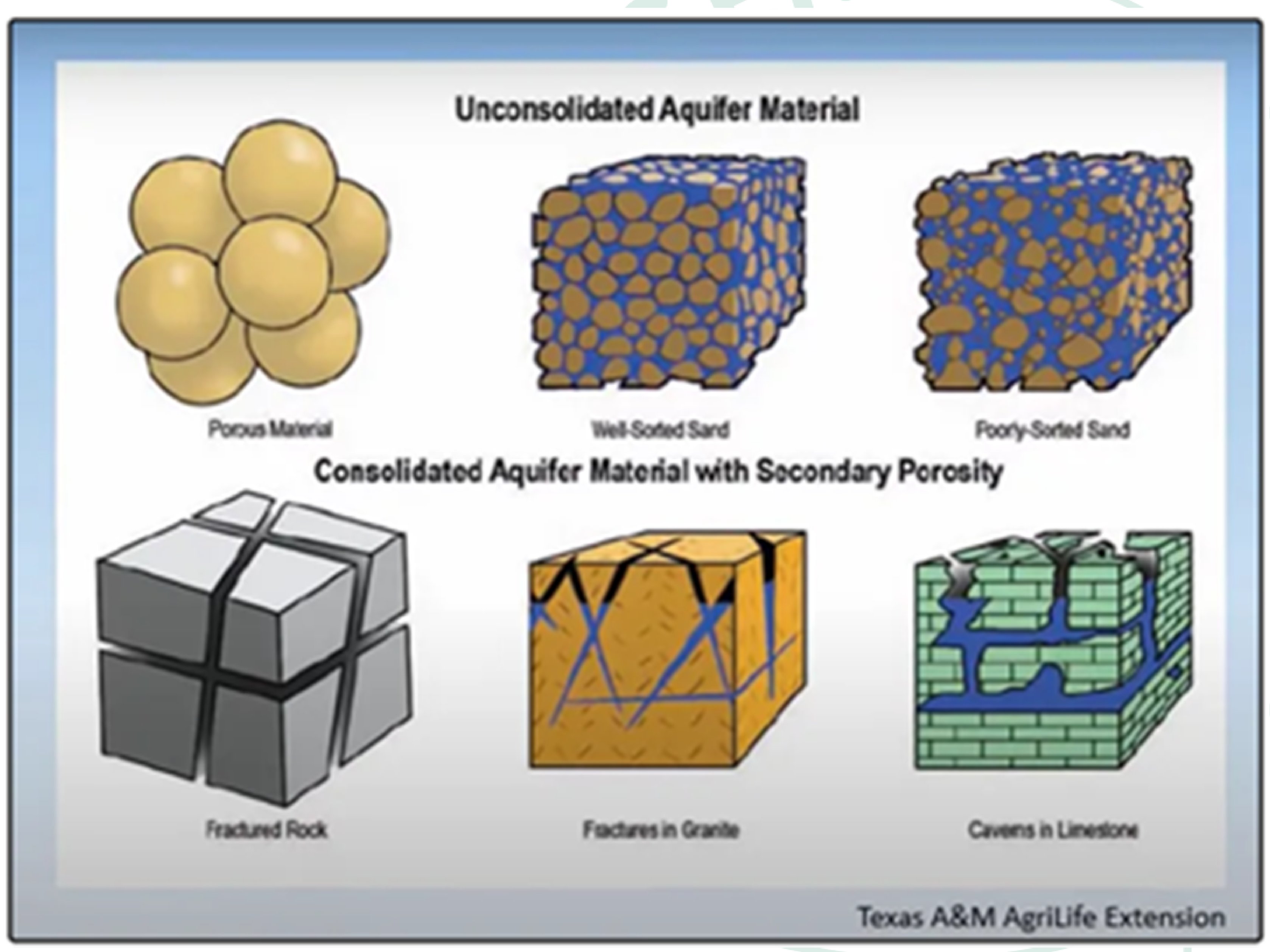


Figure 4: Types of rock formations – Consolidated and unconsolidated[7]

However, it is important to constantly monitor the downhole temperature and pressure behaviors and interactions in a typical injection well drilled for the purpose of CCUS. For this reason, permanent downhole gauges (PDHG) are installed in the wells during completion to remotely provide readings of the Bottom Hole Temperature (BHT) and Bottom Hole pressure (BHP) of the well at defined well depths. This is done using digital or fiber optic gauges which produce impulses conveyed to the surface via electrical/fiber lines and displayed on digital gadgets. These well data are captured over time and stored on servers to provide guidance on well performance. As these wells are underground and adequate predictive data is crucial, artificial intelligence plays an important role. As such in the development of these wells, it is crucial to ensure intelligent completions by deployment of permanent downhole monitoring systems.

3. The role of artificial intelligence in CCUS

The use of AI in CCUS systems is innovative. Due to AI's ability to predict upcoming events with high probability, undesirable outcomes in the development and operation of CCUS wells can be avoided. Through AI-generated output based upon received data, wells can become intelligent and gain a level of independence, augmented by human intelligence, for projections and decision making and as such

[7] Anjana Balakrishnan 'Aquifer Maps Add Accuracy to Jaltol: update on the new map layer added to Jaltol v1.1', Center for Social and Environmental Innovation, ATREE; March 2022.

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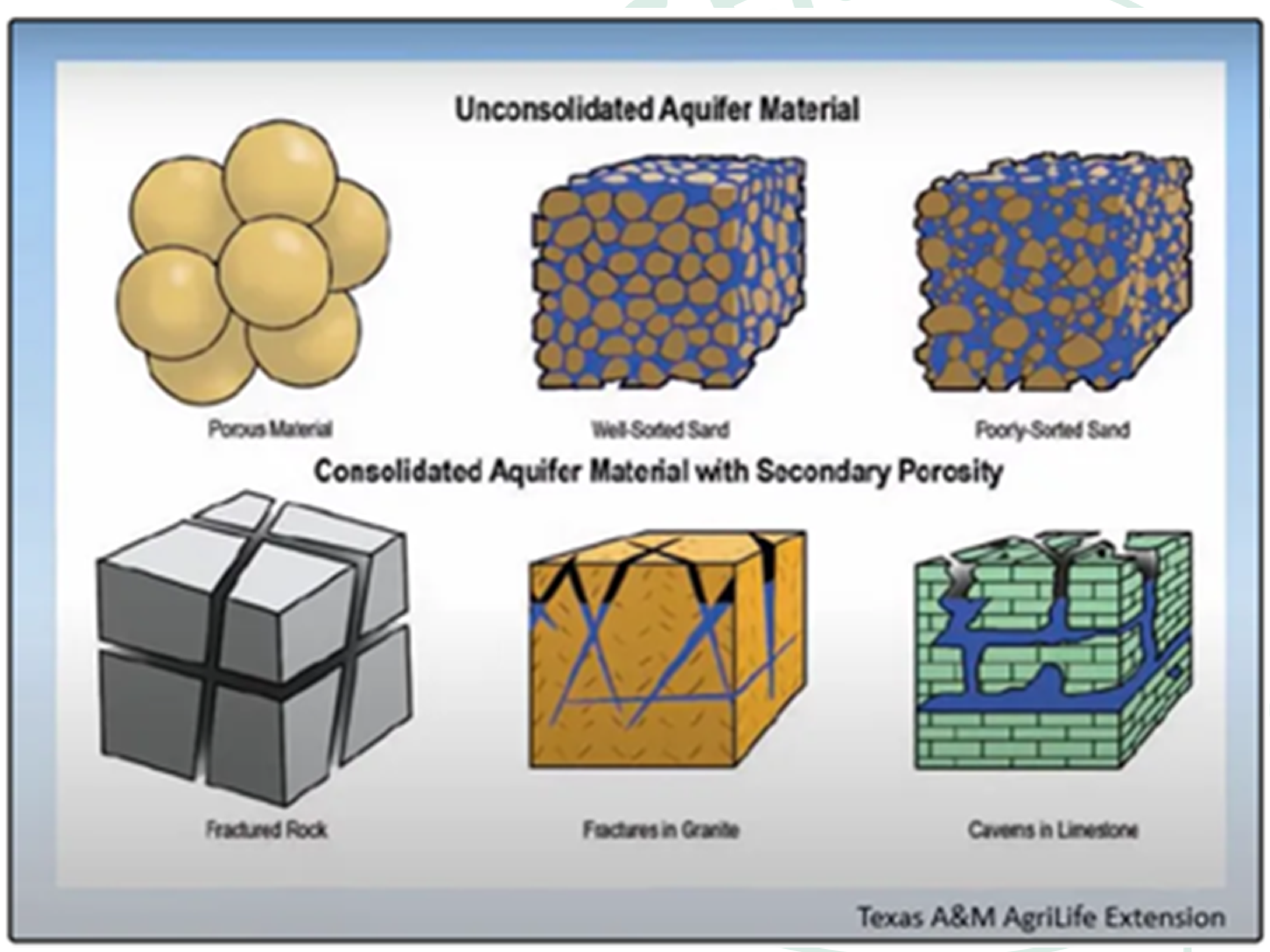

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it is easy for engineers and technical experts involved in the process to act adequately to prevent well failure, leaks, as well as pressure and temperature variation beyond acceptable limits. This will ensure that in the CCUS process, CO_2 that is injected into the wells in the earth does not escape to the environment and further cause environmental pollution.

Over the last decades, various techniques have been adopted to gather data from CO_2 injection wells. These techniques involve using digital gauges and the more recent fiber optics technology for Movement, Monitoring and verification (MMV) of CCUS wells completion. Some of these techniques used include:

1. Pressure Temperature (P/T) gauges
2. Distributed Temperature Sensing (DTS)
3. Distributed Acoustic Sensing (DAS)
4. Microseismic Monitoring (MSM)
5. Fiber VSP (Vertical Seismic Profiling)

The value of AI to this process resonates from the fact that AI can improve decisions, processes, and experiences in the CCUS process. CCUS wells are injections wells henceit is important to have reliable conformance and containment of pressure. And efficiently monitor CO_2 movement both in the wellbore and inside the storage reservoir. AI can enhance these processes, making them more predictable.

Another aspect, which is of great importance to policy and regulatory requirement, is the external mechanical integrity. This looks at assessing if there may be CO_2 migration along the path of the cement behind the casing and sipping upwards to contaminate shallower areas of the crust like aquifers used for drinking water. There are different technologies that can be used to assess external mechanical integrity. Some of the common ones include oxygen activation logging, acoustic logging, radioactive trace logging, and temperature logging. A lot of CCUS projects have moved towards temperature logging because of the operational efficiency associated with it. A typical temperature log will show the temperature behavior as we proceed deeper into the well leaving us with a graphical representation of the well temperature against the well depth. Temperature logs recorded during the well shut-in periods can be particularly informative of the status of the external mechanical integrity. Using AI, outcomes can be more predictable.

Overall, advanced insights resulting from AI processes can further scale the CCUS technology for attainment of higher business benefits through reduced costs, and more importantly, result in its broader applications leading to more wide-spread preservation of the environment through reduced CO2 emissions lessening impact on climate change.

4. Governance issues in the use of artificial intelligence for CCUS

There are key governance issues in the use of AI in CCUS.

The first of this is development of training data in the development of intelligent wells. Since AI cannot function without the right kind of information infrastructure, it is important for policymakers to pay attention to the nature of the data used to train these systems. As such, it is important to pay attention to recorded and real-time data on the well injection rate, injection pressure, well temperature taken at various well depths, and reservoir performance data taken from surveillance wells.

- The second issue is ensuring that data has the right quality and relevance for training the AI to avoid the potential for bias which can lead to errors and inconsistencies in AI functionality.

- The third issue is data privacy and use – knowing the limit to which data is to be shared or allowed to interact.

- The fourth issue is good consideration of risks in AI and the assurance of the involvement of human intelligence in decision making that is based off AI predictions.

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