RENEWELL

Converting Oil and Gas Wells to Energy Storage

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The oil and gas well lifecycle

Natural gas and oil wells are ubiquitous in our lands, from the urban landscape of Los Angeles to the rolling plains of West Texas. These wells are a testament to the widespread and historical significance of fossil fuels in providing energy for the world. Remediation of these wells after the end of their productive lives has proven an ongoing challenge. As a result, there are presently over two million so-called idle oil and gas wells in North America alone. This paper describes the processes and challenges related to these idle oil and gas wells, and lays out a beneficial solution: converting idle oil and gas wells to energy storage for the electricity grid.

A typical oil and gas well has a productive lifetime of about 20 to 30 years. When the value of the oil produced no longer exceeds the cost to produce it, the well stops producing and becomes what is called an idle well. Once a well reaches the end of its life, it must be retired and remediated through a process known as plug and abandonment (P&A). P&A often involves a plug and cement at the bottom of the well, but, in the United States, state regulations determine the particulars of the P&A process. Once it is properly sealed and has passed certain time-sensitive tests, nature is allowed to reclaim the well area.

P&A traditionally signifies the economic death of a well, but other activities continue. A well at P&A status may continue to emit greenhouse gases (GHGs) well after retirement. In a study published in the Geophysical Research Papers, 6.5% of plugged and abandoned wells emit methane to the atmosphere (Townsend-Small et al., 2016). This is equivalent to ~200,000 wells in America today. In addition, there is currently no process in place to check or repair previous P&As. Cement, like any other material, can break down over time, meaning that even if a well does not emit greenhouse gases in its early years of retirement, the material used to plug the well may degrade and allow emissions of methane and other pollutants. Without any monitoring in place, these emissions will continue unchecked and unaccounted for.

Due to these and other issues, many have called for an increased reliance on renewable energy to supply future energy needs. The rapidly declining costs of renewable energy, paired with its ability to significantly reduce GHG emissions, make it an increasingly compelling alternative to fossil fuels.

Fossil fuels, however, represent energy on demand in comparison to the intermittent nature of renewable energy. As renewable energy becomes a greater and greater portion of our energy mix, so too does the need for energy storage to balance the electricity grid when the wind is not blowing and the sun is not shining. The varying durations of time where there is no wind and/or uninhibited sunshine present the need for both short- and long-duration energy storage.

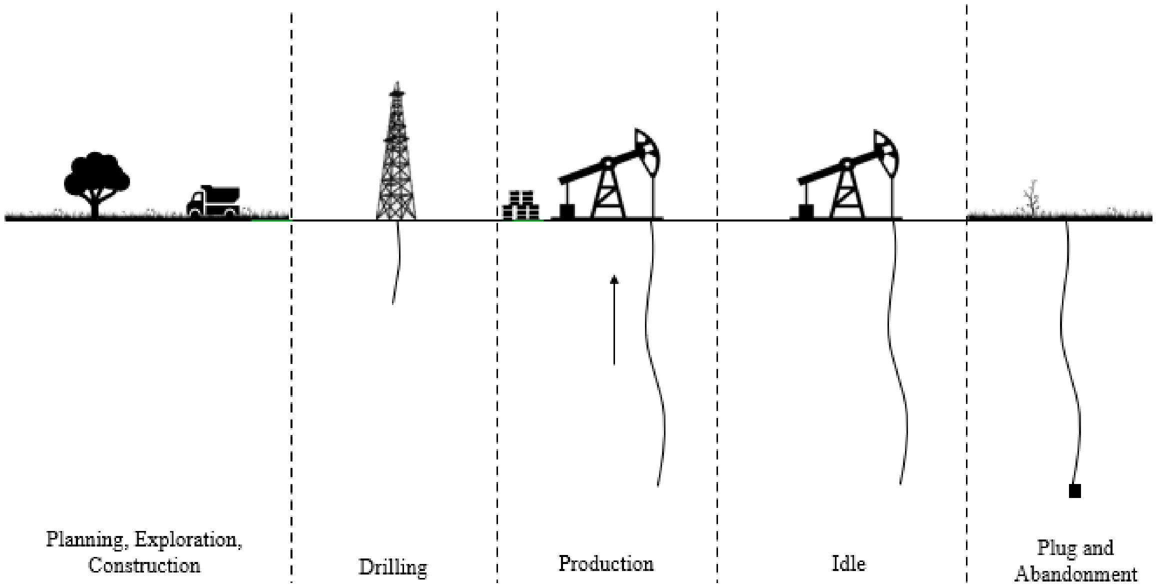

Figure 1. Today's typical life cycle of an oil and gas well

Storage is the cornerstone of renewable generation

Multiple energy storage technologies have been developed, some before the implementation of renewable energy. Pumped hydroelectric storage facilities currently make up over 90% of energy storage capacity in the United States (EPA, 2018). Other energy storage methods include batteries, flywheels, and thermal energy storage. Each method is more suited to different applications and is often restricted based on location and resource availability. For example, a pumped hydroelectric station needs a vast amount of water and a difference in elevation between an upper and lower reservoir to produce electricity. In addition, other storage technologies may not be readily available to consumer electric grids.

The need for energy storage and more cost-effective P&A were unrelated until Renewell Energy began their mission to provide an alternative P&A option by converting oil and gas wells into gravitational energy storage devices.

Gravity energy storage intersection

Currently, many gravitational energy storage devices involve tall structures and multiple weights. These structures take advantage of the principles of kinetic and potential energy. These same principles can be applied within wellbores. The following is a mathematical summary of these principles.

$$PE = mgh \qquad KE = \frac{1}{2}mv^2$$

$$PE = Potential\ Energy \qquad KE = Kinetic\ Energy$$

$$h = height \qquad m = mass$$

$$g = gravity \qquad v = velocity$$

Potential energy is dependent on the height of an object as well as the object's weight. An ant suspended an inch from the ground represents a lot less potential energy than, say, an elephant at the top of the Burj Khalifa. This potential energy can be converted to kinetic energy as the object falls and gains velocity. To create value from this conversion, the potential and kinetic energy of the system must be captured. Renewell Energy has developed a mechatronic energy conversion system comprised of a motor-generator, gearbox, and drum for this purpose. The motor-generator and gearbox harness the kinetic energy when lowering the suspended object. The weight is later lifted with excess electricity supply from the grid and held at the top of the well until electricity is desired, thereby storing the excess. Through this system, potential and kinetic energy is converted to electricity. Strategic use of these principles, has placed gravitational storage at the forefront of long-duration energy storage methods.

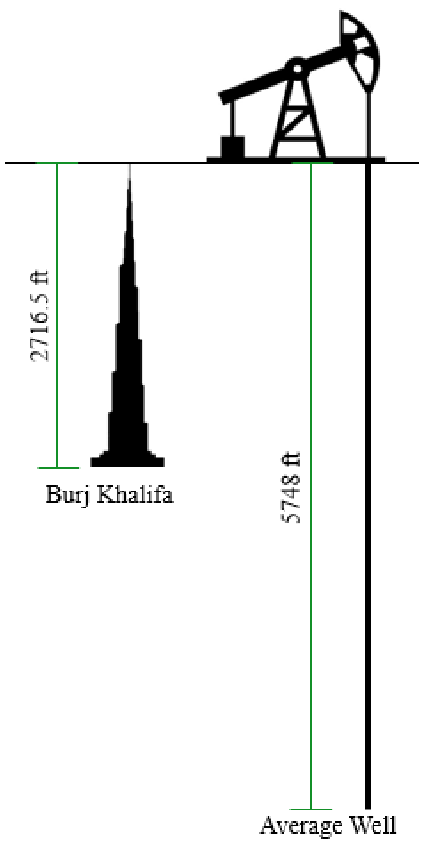

Figure 2. Comparing an average well depth (5748ft/1.08mi) to the Burj Khalifa (2716.5ft/0.5mi)

For maximum utilization of kinetic and potential energy, the best gravitational storage locations are those that present the highest vertical drop. For example, the Burj Khalifa could be used as a fantastic gravitational storage device. At 2716.5ft, the Burj Khalifa is by far the tallest building in the world and would thus present a fantastic opportunity for energy storage. However, the infrastructure required to capitalize on this building's height would hinder the surrounding city and the building's occupants. To avoid this issue, Renewell Energy intends to capitalize on the principles described previously, as well as a readily available source in much of the United States: idle oil and gas wells.

Vertical displacement in wells as an untapped resource

The principles of kinetic and potential energy apply whether the vertical drop is above or below ground. The average well in the United States is more than twice as deep as the Burj Khalifa is tall, which provides more than double the amount of potential energy. In addition, most wells have reliable access to electricity transmission infrastructure, making them suitable locations for siting new grid energy storage capacity. America's more than two million idle wells are also dispersed across every major electricity market in the country. Converting idle oil and gas wells to gravity energy storage using the aforementioned mechatronic energy conversion system has the potential to provide a significant energy storage resource for the grid and support the continued growth of renewable energy..

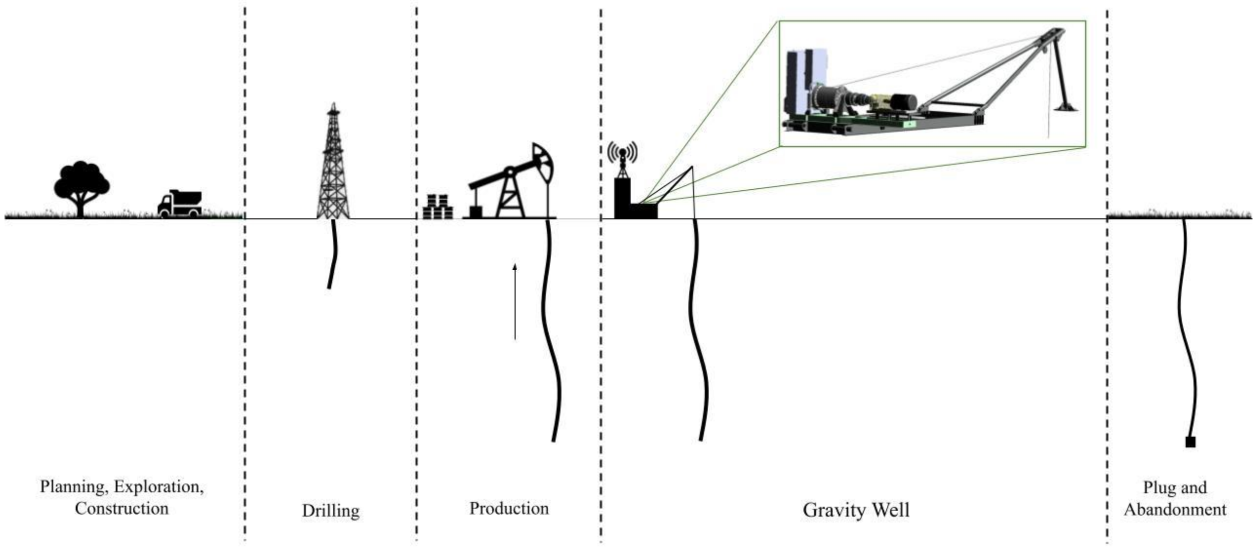

Figure 3. Future life cycle of an oil and gas well

Example Well: Well A

Consider the following case: Well A is completely vertical, with a depth of 7,000 feet and an inner casing diameter of 7 inches. A 44,500 kg weight roughly ¼ the length of the well is introduced. If the weight does not leave the interior of the well, it can traverse 5,000 feet of depth. The wire rope attached to the weight contributes to the potential energy capacity as well, weighing about 10,000 kg. Including buoyant forces, the total weight of the system is roughly 45,000 kg. Well A thus has a theoretical capacity of 186.9 kWh. Calculations can be seen below:

$$PE = mgh = 45,000\,kg * 9.81\,m/s^2 * 50($$

$$= 6.28 * 10^8\,Joules = 187\,kWh$$

If we assume a one-way system efficiency of 85% (which is expected to be a very conservative estimate), we find a 168 kWh storage capacity for Well A. This well is the equivalent of 12.5 Tesla Powerwall battery systems.

Conclusions

Of course, the above example is greatly simplified. Factors such as curvature of the wellbore (dogleg severity) and friction between the wire rope and the weight against the well walls reduce the total storage capacity of any given well. In addition, the variable nature of well geometry can also introduce variability in nameplate storage capacity in wells of the same depth.

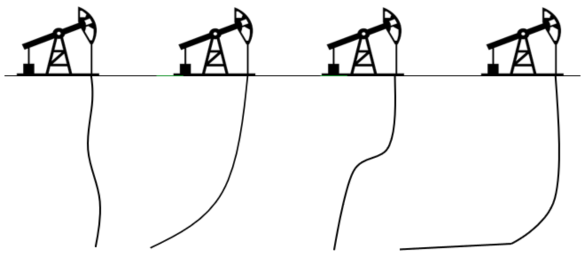

Figure 4. The four most common shapes of wells

Even so, the more than two million idle wells in the United States represent an untapped source of energy storage. If we take into account the varying depth of these wells, the presently inactive infrastructure of the oil and gas industry has the potential to store up to 108 GWh. An average 1hr discharge across this energy storage network results in 108GW, offering 90% of the US's energy storage needs in 2050 (NREL 2012).

Not all of these wells will be compatible with the infrastructure required for conversion to a gravitational storage well. The storage potential will be less due to the factors mentioned above, but even a small percentage of this total would be significant.

Vast quantities of energy can indeed be stored in the United States idle well population using gravity-based storage technology. This innovation holds the potential to revolutionize the plug and abandonment process while providing infrastructure for the renewable energy industry to grow immensely. Renewell Energy is working to harness this revolutionary potential and ensure that all wells end well.

<u>References</u>

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