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Repurposing of Legacy Oil and Gas Infrastructure for the Energy Transition: A New Frontier in Wellbore Heat Transfer Modeling

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Abstract

Wellbore heat transfer modeling has evolved substantially since its early formulations in the 1960s, when analytical and semi-analytical solutions were first developed to capture transient thermal behavior. Over the past six decades, this field has matured through progressively more realistic treatments of fluid flow, variable thermophysical properties, and complex well geometries. The growth of offshore production accelerated the need for robust thermal models capable of handling higher pressures, deeper water, and tight thermal margins, thus motivating the integration of multiphase flow correlations, wellbore-formation coupling, and improved heat-transfer closure relations. More recently, multi-physics extensions have emerged to address thermo-structural and geomechanical phenomena such as annular pressure build-up in multi-string wells, cement sheath integrity, and salt-creep deformation. These developments have increasingly blurred traditional boundaries between thermal engineering, geophysics, and structural mechanics.

This talk explores how these rich modeling foundations can be extended to meet the challenges and opportunities of the Energy Transition. In the United States alone, estimates suggest that more than two million wells are idle, unplugged, or abandoned, many of them decades old. Plugging and abandonment costs can range from tens to hundreds of thousands of dollars per well, creating a multibillion-dollar liability for operators and state agencies. At the same time, orphaned wells pose environmental risks through methane emissions and potential groundwater impacts. Repurposing a portion of this vast legacy infrastructure for subsurface thermal energy storage offers a compelling pathway to transform long-standing liabilities into distributed, long-duration energy-storage assets.

After reviewing past work on traditional oil and gas applications, the talk will discuss ongoing advances in borehole thermal storage strategies that use both sensible and latent heat, together with the coupling of these subsurface models with state-of-the-art surface energy-conversion systems for power and heat management in integrated, low-carbon energy architectures. Together, these developments outline a coherent framework for reimagining mature wells as functional components of a sustainable energy system.