AADE-22-FTCE-075

Sustainable Fluid Solutions Facilitate the Energy Transition Through Delivery of Efficiencies in Well Construction and New Levels of Environmental Performance

Vance Smith, Pawilai Hallmark, Brittany Granger, Kassie Harris, Chris Detiveaux, Alessandro Cascone, Steve Williams, Newpark Fluids Systems

Abstract

The energy transition is underway as the industry positions itself for a more sustainable future characterized by cleaner renewable resources, and a lower carbon footprint. However, the timeline of the transition will occur over decades rather than years, and it is expected that conventional oil and gas resources will continue to satisfy global demand in the coming years. The drilling and completions service sector has been proactive in helping to drive efficiencies and sustainability of technologies used in exploration and production operations. An approach characterized as Sustainable Fluids Solutions (SFS) has been used to harness deep expertise to innovate and develop greener, renewable chemistries for use in drilling and completion fluids technologies. This includes incorporating plant-based chemistries with optimal performance and which are characterized as renewable resources. These fluids-specific innovations balance the requirements relating to operational execution with far-reaching sustainability benefits. This approach has been taken to move away from conventional approaches of environmental acceptance and transition towards broader concepts of Environmental & Social Governance (ESG). This paper will also introduce metrics to characterize and assess the drilling, completion and environmental implications derived from use of these SFS. Lastly, case histories are presented to characterize the performance of these fluid solutions in drilling and completion operations.

Introduction

As the world seeks to transition to a low-carbon future, oil and gas companies are setting Net Zero targets and pursuing efforts to de-carbonize and diversify their portfolios. These include use of renewable energy sources and reduced carbon emissions from oil and gas operations. Reducing the environmental impacts from drilling, completion and stimulation operations are tactics used to arrive at this goal.

To play its part in mitigating climate change, the oil and gas sector must reduce its emissions by at least 3.4 gigatons of carbon-dioxide equivalent (GtCO2e) a year by 2050, a 90 percent reduction from current emissions. Reaching this target would clearly be easier if the use of oil and gas declined. Figure 1 shows the projected growth in energy demand and how this demand will be satisfied. Energy needs in 2050 could be more than 50% above current levels, with fossil fuels still predicted to be significant in satisfying this demand. (IEO 2021)

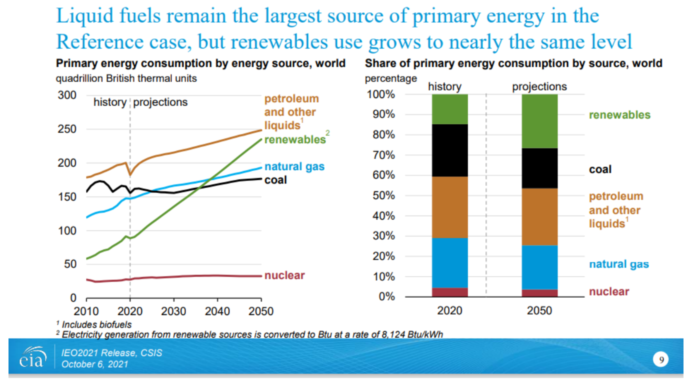

Figure 1: Projected growth in global energy demand (IEO, 2021)

The specific initiatives a company chooses to reduce its emissions will depend on factors such as its geography, asset mix (offshore versus onshore, gas versus oil, upstream versus downstream), and local policies and practices, carbon pricing and the availability of renewables. Already, many companies have adopted techniques that can substantially decarbonize operations—for example, improved maintenance routines to reduce intermittent flaring and vapor-recovery units to reduce methane leaks. (Wood Mackenzie, 2021)

Seeking improvements to their operations is one way the oil and gas industry is addressing increasing demands to clarify the implications of energy transitions for their operations and business models, and to explain the contributions that they can make to reducing greenhouse gas (GHG). The increasing social and environmental pressures on many oil and gas companies raise questions about the role of these fuels in a changing energy economy. But the core question, against a backdrop of rising GHG emissions, is a relatively simple one: should today's oil and gas companies be viewed only as part of the problem, or could they also be crucial in solving it? Three considerations provide the boundaries for this analysis. First, the prospect of rising demand for the services that energy provides due to a growing global population – some of whom remain without access to modern energy – and an expanding global economy. Second, the recognition that oil and natural gas play critical roles in today's energy and economic systems, and that affordable, reliable supplies of liquids and gases (of different types) are necessary parts of a vision of the future. And last but far from least, the imperative to reduce energy-related emissions in line with international climate targets. (Meyer, 2022).

The rapid but uneven economic recovery from the Covid-induced economic recession is putting major strains on today's energy system, sparking sharp price rises in natural gas, coal and electricity markets. For all the advances being made by renewables and electric mobility, future forecasts suggest a significant rebound demand for oil and gas energy sources. (IEA World Energy Outlook, 2021).

Energy Transition

The oil and gas industry faces the strategic challenge of balancing short-term returns with its long-term license to operate. Societies are simultaneously demanding energy services and also reductions in emissions. Oil and gas companies have been proficient at delivering the fuels that form the bedrock of today's energy system; the question that they now face is whether they can help deliver climate solutions. No oil and gas company will be unaffected by clean energy transitions, so every part of the industry needs to consider how to respond.

Clean energy technology is becoming a major new area for investment and employment, as well as a dynamic arena for international collaboration and competition. The future energy economy is predicted to be characterized as electrified, efficient, interconnected and clean. Its emergence is the product of policy actions and technology innovations, and it is expected that the momentum will be sustained by lower costs. Even while economies were impacted by Covid-19 lockdowns in 2020, renewable sources of energy such as wind and solar photovoltaic (PV) continued to grow rapidly, and electric vehicles set new sales records.

Although the energy transition is already underway, oil and gas will continue to play a key role in satisfying global energy demand. According to the United Nations (U.N.), the global population is expected to grow to 9.7 billion by 2050, with a large portion of population growth concentrated in the developing world. Energy companies, including those that produce hydrocarbons, are adapting to the changing landscape. (World Oil, 2021)

Economic effects from the Covid-19 pandemic, the changing global attitudes toward energy, and growing importance of ESG matters have disrupted the ways that oil and gas companies do business. ESG criteria are a set of standards for a company's operations that are used to evaluate programs and performance in meeting sustainability commitments. Environmental criteria consider how a company performs as a steward of nature. Social criteria examine how it manages relationships with employees, suppliers, customers, and the communities where it operates. Governance deals with a company's leadership, executive pay, audits, internal controls, and shareholder rights. The Energy Transition depends upon a forward-looking vision, with prioritization, focus and investment in technology and qualified personnel as shown in Figure 2 below.

Figure 2: New technology development to support the Energy Transition

Sustainability and ESG policies play an increasingly important role in the oil and gas sector. Pressure from shareholders have prompted publicly traded companies to create sustainability plans and commit to reducing carbon emissions. Additionally, many institutional investors and government funds have ESG policies that restrict the sectors and companies they can invest in. Publicly traded companies must pay close attention to these ESG issues or risk losing investors. (World Oil, 2021)

Although oil and gas have fallen out of favor in the eyes of many, the energy transition will take decades. Providing energy for the world's growing population is complex, and hydrocarbons are still an affordable and reliable source. The changes will not happen overnight, but over the next 20+ years, as oil and gas operators will continue to strategically navigate the changing landscape of the energy sector. (World Oil, 2021)

Figure 3: Innovative chemistry to support the Energy Transition

Sustainable Fluids Solutions (SFS)

The energy transition and ESG concepts also positively influence the service company sector, particularly regarding chemistries used in drilling, completion, and stimulation fluids. A leading, global fluids service company has embraced these new realities and has begun to harmonize technology development efforts with a corporate ESG vision as shown below in Figure 4. One key area of this is use of renewal resources, and plant-based chemistries. Renewable resources are those that have the capability to replenish, and to replace the portion depleted by usage and consumption, either through natural reproduction or other recurring processes. We can apply such resources to the drilling, completion, and stimulation fluids for use in the oil and gas industry through use of bio-renewable chemistries. Bio-renewable chemistries are defined as renewable organic materials from plants which provide feedstock for the chemical industry. Utilizing these biomass materials in the design of products and additives play a very important role in diversifying chemical industry feedstocks. They can assist in a greener, more environmentally conscious sustainable fluids solutions (SFS). Additionally, the tendency of these materials towards natural biodegradation reduces the carbon footprint and facilitates an environmentally friendly disposal after use.

Figure 4: Bio-renewable chemistries for Sustainable Fluids Solutions (SFS)

The definition of green chemistry, according to the American Chemical Society (ACS), is “*the design, development and implementation of chemical products and processes that reduce or eliminate the use and generation of hazardous substances*”. In 1998, Anastas and Warner developed the 12 principles of green chemistries that outlines a framework for making a greener chemical, process, or product (Anastas, et al., 1998). The principles include different ways that chemistry and chemical engineering can be done to achieve safer and more environmentally friendly chemical products and production process such as waste generation prevention, benign chemicals design, energy sufficiency process, and pollution prevention. One of the 12 principles that is at the forefront of the green chemistry idea is to utilize the renewable feedstock as raw materials in chemical production. Plant-based materials are derived from naturally-occurring biomass resources. Examples of these natural biomass resources are plants, trees, crops, and algae, which are generated by the photosynthesis process utilizing carbon in the air (i.e., carbon dioxide and methane) and the sun power, thus making them renewable. When the carbon in (from the air) is greater than the carbon out (from the energy used during the manufacturing process), then the carbon footprint (ΔC) can be further reduced. Furthermore, materials and waste streams generated from plant-based sources are readily biodegradables and break down under the action of living organism (e.g., bacteria, fungi) without leaving harmful effects to the environments. In this way, we can harmonize with nature’s way of doing chemistry – green, renewable, and biodegradable.

Examples of plant-based resources currently used by many industries are listed below:

- Starchy plants (wheat, corn, potato) and sugar-containing crops (beetroot)
- Oleaginous crops (with a high oil content), such as rapeseed, sunflower and soybean
- Lignocellulosic plants (with a high cellulose content) such as wood, straw, flax and hemp
- Resinous trees such as pine and fir
- Plants containing active substances such as essential oils and fragrances

To utilize plant-based resources in oilfield drilling and completion applications, there are some challenges that need to be considered and addressed. First is the availability of the materials. If the biomass resources have a lot of competition with other uses, then they might not be readily available for oilfield applications. That leads to the next challenge which is the competitiveness of the materials. To offset this, continued efforts around research and development in green, plant-based chemistries have been ongoing to build an economic, sustainable future for the oil and gas industry.

In 2002, the U.S. Department of Energy in their Vision for Bioenergy and Bio-based Products in the United States stated: “By 2030, a well-established, economically viable, bioenergy, and bio-based products industry is expected to create new economic opportunities for rural America [globalization through localization], protect and enhance the environment, strengthen the U.S. energy independence, provide economic security, and deliver improved products to consumers.” (Anastas, et al. 1998)

Table 1 shows examples of plant-based products that are currently being used in oilfield applications. These include both water-based drilling fluid products like natural polymers such as xanthan gum, cellulose, guar gum, and starch and non-aqueous drilling fluid products like fats and oil from forest chemicals (pine, palm, etc.) and oleaginous crops (soybean, rapeseed). (Adewole et al., 2019)

Table 1: Renewable materials for drilling fluid applications

Oilfield Fluid Additives	Function	Possible Source
Xanthan gum	Viscosity and thermal stability control	Modified biomaterials
Starch and cellulose	Viscosity, fluid loss additive and clay stabilizer	Natural polymers
Lignin and derivatives	Viscosity and gel strength control	Natural / modified biomaterials
Polyol	Shale inhibitor	Biomaterials
Fatty acids	Emulsifier and lubricant	Bio-derived
Scleroglucan	Viscosifier	Bio-derived
Guar gum	Thickener	Bio-derived

This publication will focus on the use of drilling, completion and stimulation technologies used in the well construction process, and how ESG concepts play into the development of these new and innovative systems.

Sustainable Drilling Fluids

Drilling fluids are required in the well construction process and some form of drilling fluid is utilized on every well drilled. Drilling fluids are classified as aqueous (water-based) or non-aqueous (oil or synthetic-based) fluids. There are various drivers which operators utilize to determine the appropriate drilling fluid system (aqueous or non-aqueous) for a particular well. From an environmental perspective, the use of either type is regulated by the local governmental authorities. This publication will outline the progression of laboratory development and field trials of an innovative high-performance, water-based mud (HPWBM). The HPWBM balances high-performance drilling with environmental compliance and harmonizes the ESG initiatives of the service company and operator community.

Non-aqueous fluids (NAF) are often the “fluid-of-choice” for challenging wells as operators balance drilling performance, with cost reduction and risk management. However, common consequences arising from use of NAF include high frequency (and cost) of lost circulation events, environmental compliance, waste management and high unit cost of the fluid. (Dye, et al. 2005)

The HPWBM provides a higher level of performance than is currently attainable using conventional water-based muds and is an environmentally compliant alternative to non-aqueous fluid (NAF).

The HPWBM formulations were designed utilizing industry-recognized testing protocols and operator-specific procedures The novel system utilizes plant-based chemistries from renewable resources, which optimize drilling while also reducing the environmental impact and exposure risks associated with use of NAF. Recent use of the HPWBM in Gulf of Mexico (GoM) ultra-deepwater led to the elimination of certain operational activities required when using NAF, to include pit and tank cleaning, as well as the use of mechanical wellbore cleanout tools. (Fisher, et al. 2021), (Kratzer, et al., 2021)

Conventional water-based mud uses bentonite clay to provide viscosity and filtration control. Although bentonite is a naturally occurring mineral, it is not renewable and its extraction through mining operations can impact the environment. The HPWBM, on the other hand, is formulated utilizing plant-based biomaterials for viscosity and filtration control. These materials include cellulosic polymers such as carboxymethyl cellulose (CMC), hydroxyethyl cellulose (HEC), and polyanionic cellulose (PAC), as well as starches and xanthan gum. These materials are derived from naturally occurring and renewable lignocellulosic and starchy plants. Fatty acids and vegetable oils processed from oleaginous crops, such as canola, rapeseed, soybean, and pine are abundant and renewable resources utilized for use as lubricants in the HPWBM. Similarly, fatty-acid derivatives from plant-based chemistry are utilized for enhancing rates-of-penetration (ROP) in the system. Additional chemistries in the HPWBM may include partially hydrolyzed polyacrylamide (PHPA), a synthetic polymer utilized for cuttings encapsulation, and polyamines for suppressing clay swelling and hydration. Choline chloride, a water-soluble, quaternary ammonium salt is readily biodegradable and is effective in reducing clay swelling, hydration, and dispersion. The chemistry has 93% biodegradation within 14 days per OECD criteria (MITI, 1992). Furthermore, choline is a dietary component for the human body, thus there are no health or exposure risks from its use. The design, formulation and testing of SFS in this publication originated from a modern, state-of-the art Technology Center, equipped with instrumentation and qualified personnel as shown below in Figure 5.

Figure 5: Laboratory testing of Sustainable Fluids Solutions (SFS)

Sustainable drilling fluids also have an important role in alternative, non-oil and gas operations. Geothermal energy has been used for centuries to satisfy general heating requirements. Electricity from geothermal resources is produced in many parts of the world, providing alternative and renewable energy sources. Geothermal plants are powered by production wells drilled to a source rock to produce steam at the surface and, depending on the location and depth, the source formation temperatures vary. The hottest geothermal resources are often located in tectonically active regions such as Southern Tuscany in Italy. These areas host national geothermal plants for electricity production and most of the geothermal district heating networks. (Pallotta, et al., 2015)

High temperature gradient exist in fields where geothermal wells are located, and the extreme temperature environment can adversely affect the properties of drilling fluids, resulting in loss of fluid stability with respect to rheological and filtration control properties. High temperature in geothermal and deep wells can be problematic and are often the primary driver for instability of drilling fluids. As a result of changes in their chemical and physical properties, problems such as gelation can occur. A series of aqueous (water-based) drilling fluids have been used in the geothermal environment. To evaluate these geothermal fluids in the laboratory, standard American Petroleum Institute (API) test procedures are used to simulate the operational environment with respect to temperatures and pressures. Important design considerations for geothermal fluids center on rheological stability, fluid loss control, and resistance to contamination.

Sustainable Reservoir Fluids

Reservoir drill-in fluids (RDF) are the first and most obvious extension of drilling fluids technology into the reservoir interval. RDF must meet the drilling performance requirements of drilling engineers, while also achieving the reservoir integrity goals of completion engineers. RDF are designed to minimize formation damage, facilitate the installation of a successful completion and exhibit compatibility with the completion fluids used in subsequent completion activities. Key features of RDF include: 1) minimally damaging to the reservoir interval, 2) reduced skin, 3) robust filtration and rheological profiles, 4) readily removable filter cakes, 5) wellbore stability and 6) flow initiation pressure reduction. (Detiveaux et al. 2020) It is important to drill and complete the reservoir section with products and systems engineered to protect the reservoir from damage and maximize the productivity and injectivity of the reservoir asset. (Gray et al. 2020)

Optimized RDF formulation and testing occurs in a specialized laboratory that has the equipment and capabilities to characterize the reservoir and perform the necessary sequence of tests to design and qualify the RDF. The laboratory is equipped with the instrumentation designed for use in the development of RDF tailored towards open hole completions as shown in Figures 6 & 7 below.

Figure 6: VHX600 Digital Microscope

Figure 7: M9100 Return Permeameter for RDF design

Filter cake breakers, which decompose and mobilize specific components of RDF filter cake, aid in the removal of the RDF filter cake and improve productivity or injectivity in the near-wellbore interval. Approaches taken to remove the filter cake include chelating and oxidizing agents, hydrochloric acid, neat organic acids, enzymes, and in-situ organic acid precursors. Breaker chemistry that dissolve calcium carbonate includes hydrochloric acid, neat organic acids (such as acetic or formic acid) organic acid precursors (which typically generate acetic, formic or lactic acid) or chelating agent**s.** (Harris et al. 2001) Use of organic acid, in-situ precursors deliver significant health, safety, and environmental advantages compared to conventional systems. Notable attributes of the in-situ acid generator technology include: a) neutral pH at surface, b) environmentally acceptable, c) controlled, delayed reaction, d) uniform removal of RDF filter cakes, e) elimination of "hot spots" and f) prevention of acid "worm-holing".

All components of the filter cake breaker system are environmentally acceptable, offering minimal exposure risk to workers at the rig-site, and can readily be mixed on surface without the use of specialized equipment. Use of organic acid precursors allows for production of acid into the area of interest at a controlled rate and with uniform coverage. The technology can also incorporate enzymes to remove specific biopolymers utilized in a water-based RDF, or surfactant technology when a non-aqueous RDF system is used.

Open hole completions require a more rigorous focus on the design of the fluids to be used to drill and complete the well. Synergies derived from use of a properly designed RDF that reduces near-wellbore damage, coupled with a breaker fluid system that uniformly disrupts or removes deposited filter cake are the end goal. Design of a suitable RDF formulation includes use of bridging software to determine the appropriate types and concentrations of chemically removable solids used as bridging particles. The particle size distribution of these bridging solids is selected based on reservoir matrix properties (pore throat size), followed by targeted laboratory testing to confirm the formulation (Granger, et al. 2022).

Case Histories

This paper highlights the journey undertaken from development to field trials of sustainable drilling and reservoir fluids designed for use in challenging wells. Case histories are presented on wells drilled with the HPWBM, RDF and breaker technologies on challenging onshore and offshore wells.

Offshore Wells – Ultra-Deepwater

A series of wells were drilled and completed from an ultra-deepwater drill ship, in water depths exceeding 8,500 ft (2,470 m), and at hole angles approaching 90° inclination. Wells in this campaign were also the first drilled and completed in a managed pressure environment in the Gulf of Mexico. Since these wells were designed as horizontals, a relatively aggressive directional plan was required to reach the shallow reservoir depth. These SFS technologies were utilized to drill an intermediate section with the HPWBM, and then drilling the open hole reservoir section with RDF to prepare for open-hole gravel pack completions.

The HPWBM was formulated with calcium carbonate as a weighting agent to ensure compatibility with the RDF and to facilitate a smooth transition to the reservoir interval. This approach eliminated pit cleaning activities which would have been required with NAF and reduced operational steps in wellbore cleanup (WBCU) operations.

Laboratory testing as well as field applications have proven the HPWBM to be inhibitive. In recent testing, accretion tendencies and dispersion characteristics were measured. The accretion testing was conducted using bentonite chips, used to simulate reactive marine formations, also referred to as "gumbo", which frequently create issues with bit balling and accretion when using WBM. These accretion tests clearly show the performance of the HPWBM in suppressing clay swelling and hydration of reactive clays commonly encountered in offshore drilling applications.

Shale dispersion was also evaluated by exposing field samples of reactive shale to the HPWBM, with a recovery rate greater than 94%. Additional toxicity testing was completed and confirmed that the HPWBM met the environmental compliance requirements for use in the GoM.

The HPWBM formulation produced a very stable rheological profile that was easily transferred from the laboratory to large scale mixes at a liquid mud plant (LMP). The 120ºF properties were measured in a laboratory setting where the fluid was mixed using standard laboratory mixing equipment and are compared to the averaged rheological properties from each of the five 2,000 bbl batches built at a LMP using the same fluid formulation.

The intermediate sections were drilled with a newly developed HPWBM to eliminate operational steps, and balance drilling performance and environmental compliance objectives. Additionally, the need for a dedicated WBCO tool run was eliminated by switching to a HPWBM. Use of the HPWBM resulted in a streamlined workflow, with a reduced number of operational steps and without compromising drilling performance. The customized HPWBM was used to drill the 12.25-inch intermediate interval and all planned performance specifications, such as wellbore stability, rate-of-penetration (ROP), reduced torque and drag, as well as prevention of bit balling and accretion were achieved. Environmental benefits derived from use of the HPWBM included reductions in Health, Safety & Environmental (HSE) exposure and the elimination of potential waste streams

Afterwards, fluids related operations involved displacement of the HPWBM to an RDF. The spacer train was designed and tested in the laboratory to ensure stability, compatibility, and performance for the planned displacement. The displacement hydraulics were modeled following a process that optimized the pump rates, annular velocities, and spacer contact times for each displacement sequence. The open-hole section was then drilled to total depth without issues. The RDF density was matched to the density of the HPWBM and the displacement was performed whereby the RDF system met the target specifications while the open hole interval was drilled.

An important design consideration for the RDF was wellbore stability, due to several lengthy shale intervals to be encountered when drilling the reservoir interval. The HPWBM, RDF and brine provided good shale inhibition while drilling these intervals, which as key to getting screens to bottom and to facilitate completion of gravel pack operations. At total a solids-free running fluid (S-FRF) was placed in the hole prior to running screens. The well was displaced to brine with gravel pack screens positioned in the well. The spacer train design was customized for the water-base RDF and the engineered displacement operation achieved the operator's specifications for the completion brine. These performance specifications (nephelometric turbidity unit (NTU) and suspended solids) were achieved after circulating one and half well volumes. The lost circulation material (LCM) decision matrix, and related products, were employed on this well and downhole losses were eliminated during open-hole gravel pack (OHGP) operations in this controlled mud-level (CML), managed pressure drilling (MPD) environment.

Use of these innovative fluid systems, in conjunction with modeling software, well design, and facilities drove operational efficiencies and cost reductions. Key deliverables from these projects include:

- Full environmental compliance
- Value delivery in narrow pressure window
- Reduction in downhole losses while cementing
- Reduction in downhole losses in depleted zones
- Elimination of stuck pipe in depleted zones
- Optimized hole cleaning efficiency
- Management of static and dynamic barite sag
- Improvements in HSE and operational efficiencies
- Reduction in non-productive time (NPT)

Onshore Wells – Permian Basin Unconventional

NAF have become the fluid-of-choice for drilling Wolfcamp horizontal wells due to perceived performance related to increased rates of penetration and reduced torque and drag. (Connell et al., 2018) However, in recent years, the increase amount of gas influxes, water flows and severe lost circulation in the Wolfcamp due to a larger man-made fracture network have increased the risk of spending tens of thousands on lost fluid, disposal and fluid reconditioning. The ever-increasing price of diesel and base chemicals used in non-aqueous fluids adds to increasing expense of these systems.

The Wolfcamp formation is found throughout the Permian basin. Oil and gas developments and crude production from the Wolfcamp have increased over the past decade and now drive nearly one-third of total production in the Permian. The industry's movement towards clean, sustainable well-site practices coupled with longer lateral intervals, along with a demand to deliver wells faster and more economical, has created compelling challenges for drilling fluids used in well construction. The challenges of drilling extended reach Wolfcamp shale laterals demand a fluid that provides a high level of torque and drag reduction (lubricity), hole cleaning, along with a stable wellbore. As a result, the selection process for drilling fluids is critical to project success.(Davis, et al. 2022)

In a departure from conventional practices, the operator utilized an engineered approach to deliver high-performance drilling and environmental excellence through use of a new HPWBM in the Wolfcamp horizontal wells. Use of the HPWBM, designed for unconventional drilling operations, resulted in improved well economics and records set in drilling performance, including footage per day and days to drill the lateral sections. This paper presents advancements made in HPWBM design through a side-by-side, in-field comparison of fourteen (14) wells drilled with the HPWBM, versus offset wells drilled with NAF. Use of HPWBM resulted in improved well economics, a reduction in environmental impact and records set in drilling performance, including footage per day, days to drill the lateral sections and a record well from spud to total depth

The use of HPWBM exceeded our the operator's expectations with regard to reductions of operational time and well construction costs. Summary of results:

- A total number of days per well reduced by 37%
- Average drilling day in lateral reduced by 57%
- Average footage drilled per day increased 31%
- Average footage drilled per day in lateral section increased 57%
- Average reduction in cost per foot (in lateral) of 7%
- Average reduction of 7.4 days per well
- Savings of $533,520 per well
- 53% reduction in fluids costs
- Record well drilled in 10 days
- Reduction in diesel of 33,600 gallon/well
- Reduction in diesel costs of $85,344/well
- Reduction in trucking costs of $11,250 in savings.

Carbon Emissions Calculator

Companies in our industry increasingly have taken on the responsibility to make a positive impact within the communities they live and work. While the world challenges the energy industry to become more environmentally responsible and efficient, service companies are tasked with developing technologies that enhance sustainability programs and reduce the environmental impacts from their use. Operators are increasingly scrutinized through the lens of ESG factors, to include regulatory pressure and corporate Net Zero goals and objectives.

There are many readily available carbon footprint calculators designed to characterize household and consumer impact on greenhouse gas (GHG) emissions. A calculator has been developed to identify the carbon footprint of activities in the well construction and completion processes which involve use of drilling, completion, and stimulation fluids.

Figure 7 below shows the percentage of green-house gas (GHG) emissions that originate over the crude oil value chain, from downstream well construction and production (11.6%), through mid-stream transport, refining and ultimately to combustion (81.1%). (ARC, 2016)

Below is an overview of the workflow mapped to the drilling, completion, and stimulation fluids carbon calculator:

- Activities identified and assigned a power source
- Activities assigned variables such as hours operated, and km/miles travelled
- Quantity power consumption (kilowatts per hour) or fuel consumed (gallons per hour)
- Apply GHG coefficients to arrive at tons for CO2 equivalent

Greenhouse gas (GHG) emission coefficients can be identified for a variety of power sources and fuel types from independent and global sources:

- Pounds CO2 per gallon diesel = (22.38)
- 1 kWh = (0.85) pounds CO2
- 1 kWh = (0.02457) gallon diesel
- Offshore average rig fuel usage between 22-32 cubes/day (242-352 gallons per hour)
- Onshore average rig fuel usage between 3,000-4,000 gallons per day for a 1500 HP triple while drilling
- Semi-trucks (5.9 – 7.2 miles per gallon) fuel efficiency.

Once all variables have been input in the calculator and the correct CO2 coefficient are applied to measured consumption, CO2 emissions are then calculated for the operation.

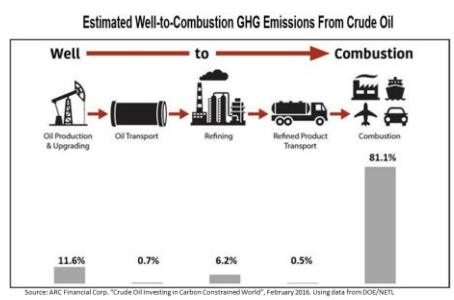

Figure 7: Well-to-Combustion GHG Cycle

The carbon emissions calculator was used to understand the impact of use of the HPWBM on reduced emissions on a multi-well campaign in the Permian basin. Figure 8 below shows a comparison of 12 wells drilled from a single rig, with 6 drilled with NAF and 6 wells drilled with the HPWBM. The average number of days to drill these wells was 20 days/well with NAF, which was then reduced to 13 days/well when using the HPWBM to drill similar well trajectories and depths. ROP in the laterals was nearly doubled through use of the HPWBM (compared to NAF) in the lateral sections. This 7-day reduction time, coupled with elimination of trucking and deliveries typically associated with use of NAF, resulted in a 37% reduction in CO2 emissions.

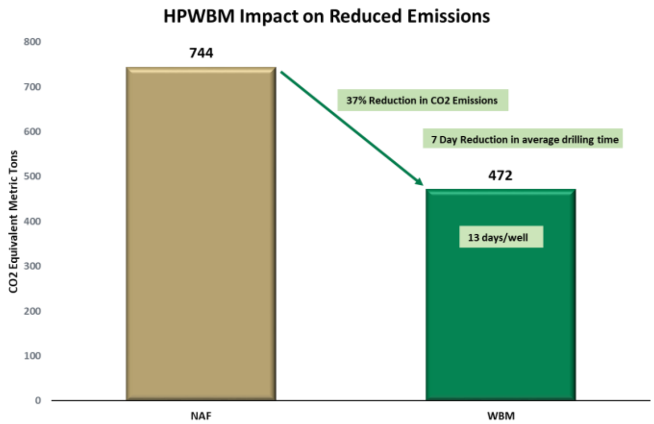

Figure 8: GHG emissions reduction through use of the HPWBM

Conclusions

- The energy transition is underway as the industry positions itself for a more sustainable future characterized by cleaner renewable resources, and a lower carbon footprint
- Oil and gas companies are setting Net Zero targets and pursuing efforts to de-carbonize and diversify their portfolios
- Societies are simultaneously demanding energy services and reductions in emissions
- No oil and gas company will be unaffected by clean energy transitions, so every part of the industry needs to consider how to respond
- Although the energy transition is already underway, oil and gas will continue to play a key role in satisfying global energy demand
- Environmental, social, and governance (ESG) criteria are a set of standards for a company's operations that are used to evaluate programs and performance in meeting sustainability commitments
- The energy transition and ESG concepts also positively influence the service company sector, particularly regarding chemistries used in drilling, completion, and stimulation fluids
- A leading, global fluids service company has embraced these new realities and have begun to harmonize technology development efforts with a corporate ESG vision
- Utilizing renewable biomass materials plays an important role in diversifying chemical feedstocks & will assist in a greener, more environmentally conscious sustainable fluids solutions (SFS)
- Challenges to use of plant-based chemistry in oilfield applications include competition for availability & economic viability
- Newly developed HPWBM portfolio utilizes plant-based chemistries from renewable resources
- HPWBM portfolio has been utilized in offshore deepwater, onshore unconventional and geothermal drilling
- Carbon calculator has been developed to characterize GHG emissions arising from drilling & completion activities
- HPWBM reduced drilling days by 7 days on a 12-well campaign in the Permian, with significant ROP increase in the lateral
- Use of the HPWBM translated to a 37% reduction in CO2 emissions compared to use of conventional NAF

Acknowledgments

The authors wish to thank Newpark Resources for permission to publish this paper. We also wish to recognize the technical contributions of Daryl Cullum, Christine Nguyen, Jake Komaromy, Huan Du, Antoine Thuriere, Robert Christian, Nathan Emery, Josh Harton and Zoraida Vazquez Colon to this publication

Nomenclature

SFS = Sustainable Fluids Solutions
ESG = Environmental & Social Governance
CO_2 = Carbon Dioxide
GHG = Greenhouse Gas
PV = Photovoltaic
U.N. = United Nations
ACS = American Chemical Society
HPWBM = High-Performance, Water-based Mud
NAF = Non-Aqueous Fluid
GoM = Gulf of Mexico
CMC = Carboxymethyl Cellulose
PAC = Polyanionic Cellulose
HEC = Hydroxyethyl Cellulose
PHPA = Partially Hydrolyzed Polyacrylamide
OECD = Org. for Economic Cooperation & Development
API = American Petroleum Institute
RDF = Reservoir Drill-in Fluid
WBCO = Wellbore Cleanout
WBM = Water-based Muds
HSE = Healthy, Safety & Environmental
ROP = Rate-of-Penetration (feet per hour)
S-FRF = Solids-Free Running Fluid
LCM = Lost Circulation Materials
OHGP = Open-Hole Gravel Pack

NTU = Nephelometric Turbidity Unit
CML = Controlled Mud Level
MPD = Managed Pressure Drilling
NPT = Non-Productive Time (hours)
CO2 = Carbon Dioxide

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