RESERVOIR SOLUTIONS

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Ryder Scott launches price differential freeware

Ryder Scott has designed and released its *Reservoir Solutions* price differential program for Excel. The download link for the HC Price Xplot program and the other 13 freeware applications is posted on the website.

Public issuers apply differentials to benchmark prices, adjusting them for quality — including gravity and sulfur content — and for energy content, transportation fees, and regional and local differences. The adjusted prices are used to prepare annual reserves filings with the U.S. SEC.

HC Price Xplot is designed to assist the professional engineer easily and quickly to determine price differentials, which are the differences between "hub" or reference prices and the prices actually received at the wellhead. The template assists in determining the expected wellhead price based on any given benchmark hub price.

"It is important to remember that for determining differentials, you should only use monthly average hub prices and monthly average wellhead prices in the analysis," said **Fred Ziehe**, advising senior vice president. "Do not mix daily prices and monthly averages for received prices while determining the differential."

Users apply differentials to reference prices, such as the SEC 12-month average price, NYMEX price, average differential to the indices derived from monthly index prices and lease operating statements, etc.

Today, thousands in the industry the world over use the 13 Excel add-ins.

Price differentials are sometimes referred to and based on the following:

1. The "delta difference" between wellhead price and hub price
2. Ratio of wellhead price to hub price
3. More rigorous method in which the actual received prices are cross-plotted against the hub price, with a "best-fit" line drawn to represent the equation for the differential. This is sometimes called the dynamic differential method.

The differential analysis will appear as an equation for the "best-fit" line (below) through the data on the cross-plot of Field Prices vs. Benchmark Prices. This equation represents the relationship of the differential between field price and hub price, and can be entered into ARIES.

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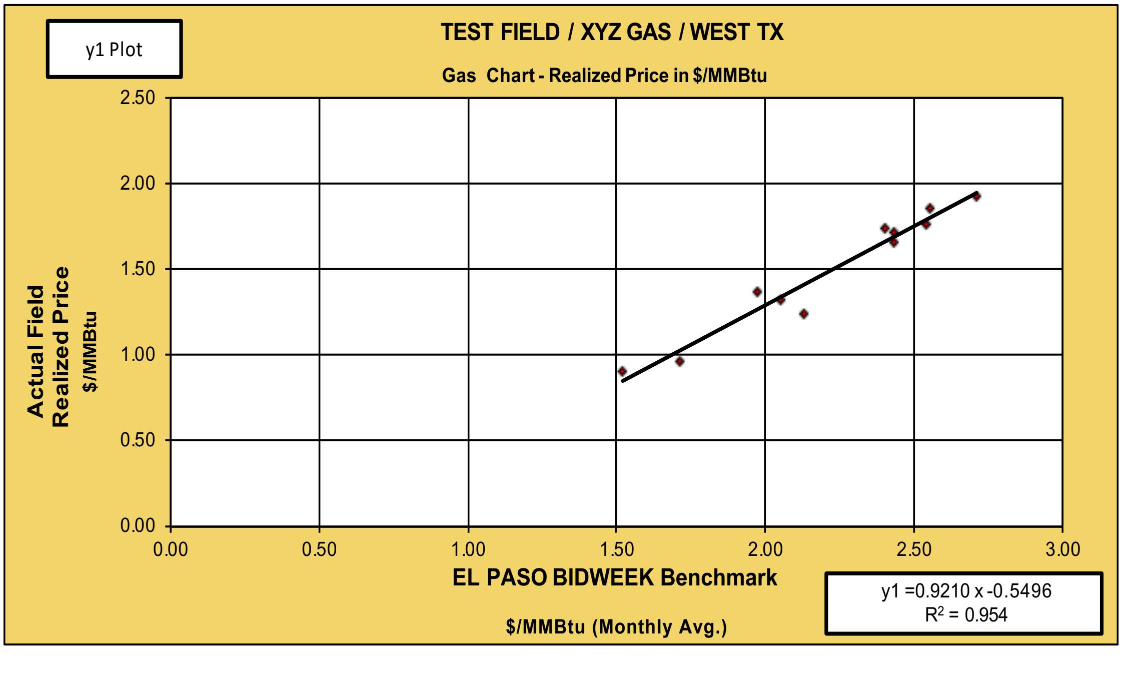

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HC Price Xplot easily determines the differential for all three of those methods with minimal effort and data.

"Keep in mind that if you are using an escalated pricing forecast, you may find that the differential will vary at low prices vs. higher prices. In that case, the best-fit line from the cross-plot may prove the most useful method," said Ziehe.

For support, contact **David Garcia**, vice president, at David_Garcia@RyderScott.com or by phone at +1-713-651-9191, ext. 5509. Additional support is provided by Ziehe at Fred_Ziehe@RyderScott.com or by phone at +1-713-751-5576.

More than 20 years ago, Ryder Scott released its first *Reservoir Solutions* freeware program and by 2006, the number of petroleum engineering and geoscience applications had grown to 10. Today, thousands in the industry the world over use the 13 Excel add-ins.

Reservoir Solutions user manuals are included in all Excel add-ins. All posted freeware programs produce presentation-quality, on-screen views and printer-friendly, hard-copy output.

Ryder Scott also distributes USB drives with the freeware from its booth at the SPE-ATCE and NAPE events.

***Editor's Note:** Ryder Scott does not guarantee or warrant the accuracy or reliability of the Reservoir Solutions software and disclaims its fitness for any particular purpose.*

***Acknowledgements:** Many thanks to Ziehe and Bob Paradiso, vice president, for their invaluable contributions in making this program an excellent, user friendly product.*

Office 365 "fix" necessary to display RS freeware template in Excel

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Reservoir Solutions freeware downloaders on Office 365 have reported problems with loading and displaying the engineering menus. After installation, the menus normally appear on the add-ins tab of the Excel ribbon, but not for Office 365 users.

The following procedure may solve the loading problem: By default, the start screen is the first screen of Excel to display when the program is opened. For users who see the start screen displayed on startup, turn it off. The start screen blocks the auto-run procedure that creates the engineering menu.

Steps to fix problem: In Excel, go to File, then Options to display the Options Dialog Box. It defaults to the General category. Scroll down to the last item under Start Up Options, and uncheck the box for "show the start screen when this application starts." Click OK and restart Excel.

The procedure may not work in every case. For assistance, please contact **David Garcia**, vice president, at David_Garcia@RyderScott.com.

Note: Templates or workbooks created in previous versions of Reservoir Solutions software are not compatible with current versions.

Third-party assurance of ESG set to grow, says E&Y

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Ernst & Young released a YE 2020 U.S. oil and gas benchmarking study on Aug 30, and part of its focus was on ESG disclosures. The report analyzed the industry's 50 largest publicly traded E&P companies.

"ESG and sustainability have become essential to attracting capital and creating long-term value for all stakeholders. Interestingly, very few companies in our study — only 16 percent — are providing third-party assurance over ESG metrics. Due to a lack of standardization and companies following various frameworks, the importance of third-party assurance to investors is going to grow," the report stated.

The U.S. SEC is starting to consider disclosure requirements and standards in ESG reporting by public companies.

"ESG independent certification is becoming more important now that the SEC has also questioned the reliability of the ESG reports," said **Herman Acuña**, executive vice president at Ryder Scott, who heads up the firm's third-party ESG validation and verification services.

At YE 2020, more than three-quarters of the companies published an ESG or sustainability report. Of the studied companies, ESG goals were most often identified for environmental topics (53 percent), rather than goals for social (33 percent) or governance (10 percent).

"Some have advocated that the (SEC) commission rely on the work of one or more external third parties to devise and maintain updated ESG disclosure standards and then incorpo-

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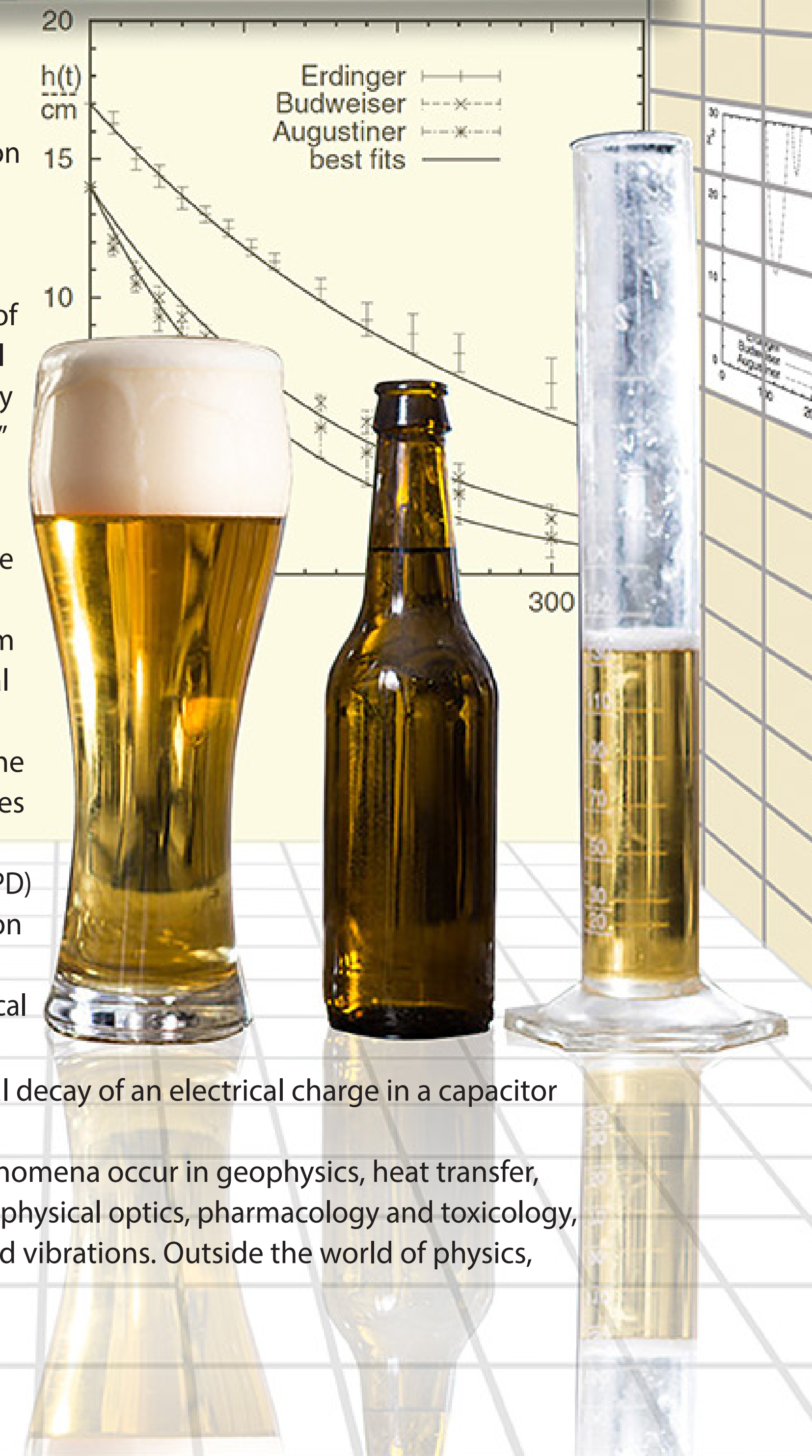
Oneness in nature: Beer foam, oil production and the universe

$$h^{th}(t) = h(0)\left(1-\frac{t}{T}\right)\theta(T-t)$$



What do end-stage oil production and beer foam have in common? They both exponentially decline.

Twenty years ago, students at the Ludwig Maximilian University of Munich demonstrated exponential decay of volumes of beer froth. They measured the height of the "head" for several brands of beer.

Arnd Leike, at the university, designed the experiment and wrote a paper.

In the oil industry, another term for exponential decline is terminal decline. For tight wells, it bolts on to the Arps hyperbolic model as the exponential tail. Petroleum reserves engineers also use a "stretched" exponential production decline (SEPD) model to estimate future production from tight, fractured formations.

Surprisingly, decay in an electrical charge is an analog for SEPD. The model is based on the exponential decay of an electrical charge in a capacitor under a constant external load.

Other exponential-decay phenomena occur in geophysics, heat transfer, chemical reactions, luminescence, physical optics, pharmacology and toxicology, radioactivity, thermoelectricity and vibrations. Outside the world of physics,

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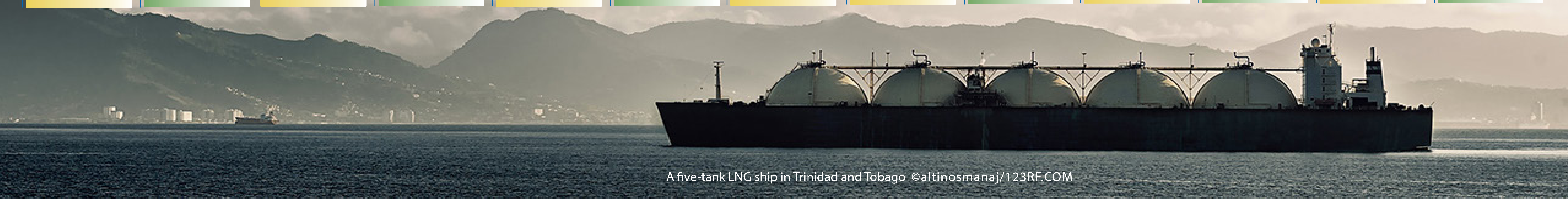
Ryder Scott, government and E&P companies work together to attain success in T&T

- **1936** — First employee of Ryder Scott, Donald T. May, analyzed cores brought back from T&T by founder Harry M. Ryder.
- **1972 to 1987** — Evaluated 22 oil and gas fields using an intensive geologic approach in estimating the volumetrics.
- **1973 to 1981** — Performed gas-deliverability and reserves studies of a license area offshore the east coast.
- **1978** — Performed extensive study of all offshore gas reservoirs on the east and west coasts.
- **1980 to 1981** — Evaluated gas fields offshore the east, southeast, west and north coasts for the Ministry and National Energy Corp.
- **1982 to 1994** — Performed several independent studies for the government as it pursued a strategy of monetizing T&T gas reserves.
- **1995** — Conducted an independent determination of gas reserves and resources for the National Gas Co.
- **1998** — Conducted integrated field development studies of several fields in the Gulf of Paria.
- **2000** — Evaluated gas volumes, commercial structures of Atlantic LNG Co. projects, including economics and international marketing.
- **2001 to 2003** — Conducted countrywide deterministic and probabilistic evaluations of 100 fields as part of the country's gas master plan.
- **2005 to 2007** — Audited gas resources and reserves. Evaluated complicated petrophysical data of the thinly laminated reservoirs.
- **2008** — Began a country-wide evaluation of the petroleum reserves and resources of the oil fields.
- **2008 to present** — Conducted countrywide evaluations of offshore gas reserves. T&T uses reports to develop national energy policies and long-term gas contracts.


A five-tank LNG ship in Trinidad and Tobago ©altinosmanaj/123RF.COM

Trinidad and Tobago has many positives to celebrate over the last several reserves audits, replacing 100 percent or more proved reserves and C1 contingent resources. Those volumes are represented in the country's technically recoverable resources (TRR) from 2016 to 2019.

TRRs are those quantities of petroleum producible using current available technology and industry practices, regardless of commercial or accessibility considerations. C1 volumes have the same level of technical certainty as proved reserves but have one or more commercial or accessibility constraints.

At a press conference, **Herman Acuña**, executive vice president at Ryder Scott, said, "Most of the gains came from successful exploration of deepwater blocks."

EOG had success with the Mento and Osprey East exploration wells and BHP had deepwater success with the Bele, Boom and Tuk exploration wells.

In 2019, operators drilled the largest number of exploration wells in the past 20 years at 16, a record that was last equaled in 2001, stated **Christian Welsh**, Ministry of Energy and Energy Industries, in an SPE technical paper this year.

Steeped in history and geology

Ryder Scott history with T&T began 85 years ago, a year before the firm was incorporated in Pennsylvania. In 1936, Ryder Scott's first employee, **Donald T. May**, developed chip-coring analysis using core samples taken from unconsolidated sands in Trinidad. Using that innovative technique, May was able to analyze porosity, permeability, saturations and other properties from a single plug of sand.

Decades later, Ryder Scott evaluated 22 oil and gas fields for Amoco Corp., National Energy Corp. and the government from 1972 to 1987. The firm used an intensive geologic approach in estimating the volumetrics, including generating structure and isopach maps for every pay sand in every field.

Today, the reservoirs of interest still exhibit a high degree of geological complexity, and are highly faulted with multi-layered pay zones.

Deji Adeyeye, vice president, recently made a presentation on the T&T work, and said, "The complexity of the subsurface leads to a large number of reservoir data records and a significant amount of geology work underpinning the gas reserves estimates, which are based on volumetrics, material balance (P/Z) and performance."

As data began accumulating, Ryder Scott geologists saw the opportunity to integrate a geographic information system (GIS) with its mapping, so in 2017, the project began. GIS technology has advanced capabilities in spatial analysis and visualization of subsurface data. Ryder Scott set up ArcGIS as its GIS.

Brett Gray, senior vice president and geologist, said, "Initially, it was partial fact finding and digging through Ryder Scott archives to find missing pieces of data that the ministry had not collected from the operators themselves."

"With GIS, we can create, manage, analyze and generate maps. GIS links spatial with non-spatial data," said Gray.

He uses Microsoft applications Power BI and the Power Query base function in Excel with ArcGIS.

"The power in these apps is they allow you to quickly extract, transform and load data into common data tables that can be pushed into the GIS project," he said. "It allows me to create match tables, normalize operator names and remove typos in a quick, efficient manner vs. going through every spreadsheet in every year and table to ensure all those pieces are normalized."

Ryder Scott is working on using more open source database types.

"This will help with future implementation and allow us to implement cross-platform support," said Gray. "We can load information from ArcGIS into Spotfire. I've got a Spotfire dashboard set up and you can click a field and it will provide map information, locations, etc."

Welsh stated in his paper that, "the Ministry of Energy and Energy Industries has and will continue to manage the hydrocarbon resources with the aid of independent petroleum consultants to assist in keeping the public aware of important developments in the oil and gas sector and to guide government policy in the development of the country's hydrocarbon resources."

The SPE paper, "20 Years of Independent Oil and Gas Audits: The Trinidad and Tobago Story," SPE-200985-MS, is available at onepetro.org.

Carbon Capture, Utilization and Sequestration (CCUS) Value Chain

Limiting global temperature increases to 1.5 °C by 2050 will require an additional 5,635 MTPA (million metric tonnes per annum) of carbon capture capacity to meet the climate target set by the Intergovernmental Panel on Climate Change (IPCC). As of 2021, 39 MTPA of deployed carbon capture capacity exists worldwide, with 43 MTPA of full-scale projects currently in various stages of development. The striking difference in available vs. required carbon capture capacity shows the market is ripe for new CCUS projects.

These projects in development are concentrated mostly in the U.S., Northern Europe, and China, and are driven by carbon price incentives. The facilities are strategically located in industrial belts based on carbon sources and proximity to suitable reservoirs or formations. Nevertheless, CCUS economics can be challenging, making it necessary to understand the different segments of the CCUS value chain to bring projects to fruition.

Figure 1.0 depicts a case study for post-combustion carbon capture from a coal power plant. The process involves capture of 1.4 MTPA of CO_2 from flue gas from a 240-MW turbine. The supercritical-state fluid is transported via an 82-mile pipeline and injected into a well at an Enhanced Oil Recovery (EOR) project.

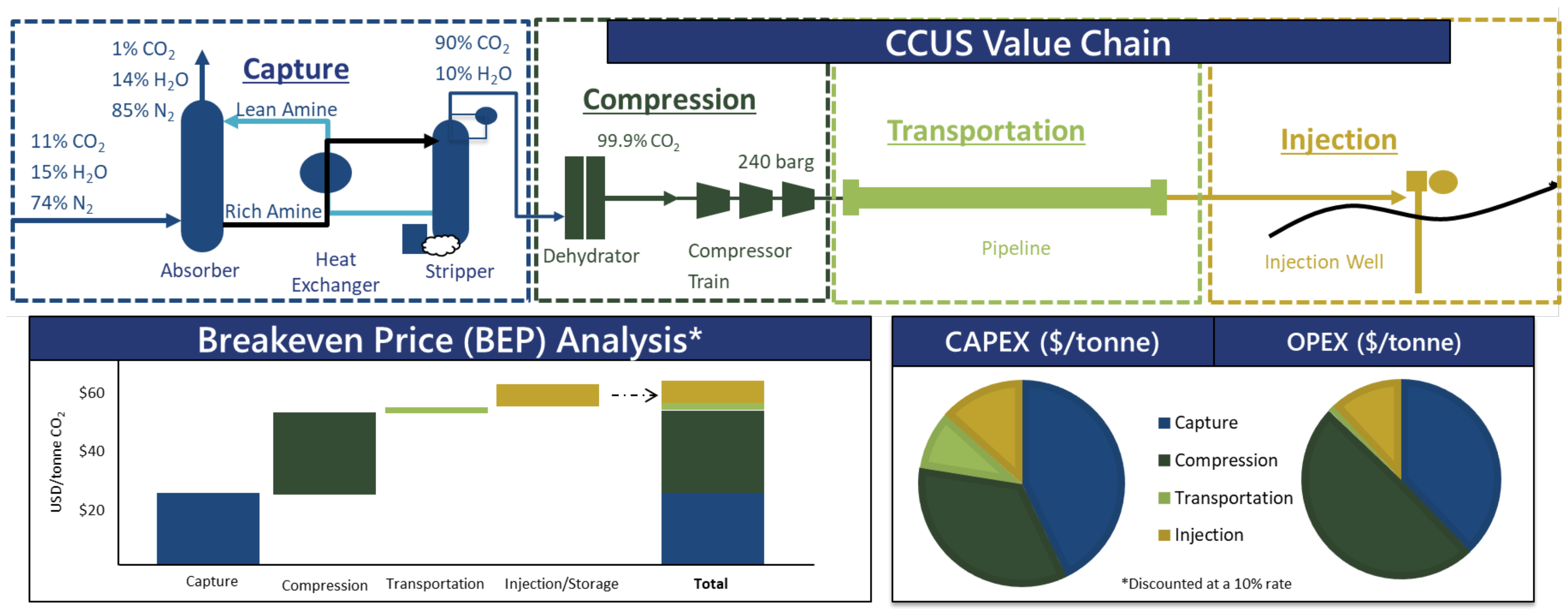


Figure 1.0: CCUS Value Chain and Project Economics

The economics also are shown on Figure 1.0. A vertically integrated project connects the value chain segments — capture, compression, transportation and injection — and results in a breakeven price of $65 per tonne of CO_2. That is a 10% rate of return on the investment. The equivalent price of CO_2 reflects the benefits in incremental oil recovery in EOR projects and related carbon capture tax credits. The capital expenditures (CAPEX) and operating expenditures (OPEX) in the value chain indicate that capture and compression, respectively, are the main contributors to the costs.

Academic and industrial jargon have inconsistent terms to describe the capture configuration, and show the location of CO_2 capture and the technology used to separate and generate the pure CO_2 stream. Although configuration and technology are interrelated, Figure 2.0 depicts the processes and equipment organized by capture and separation configurations and their typically associated technologies.

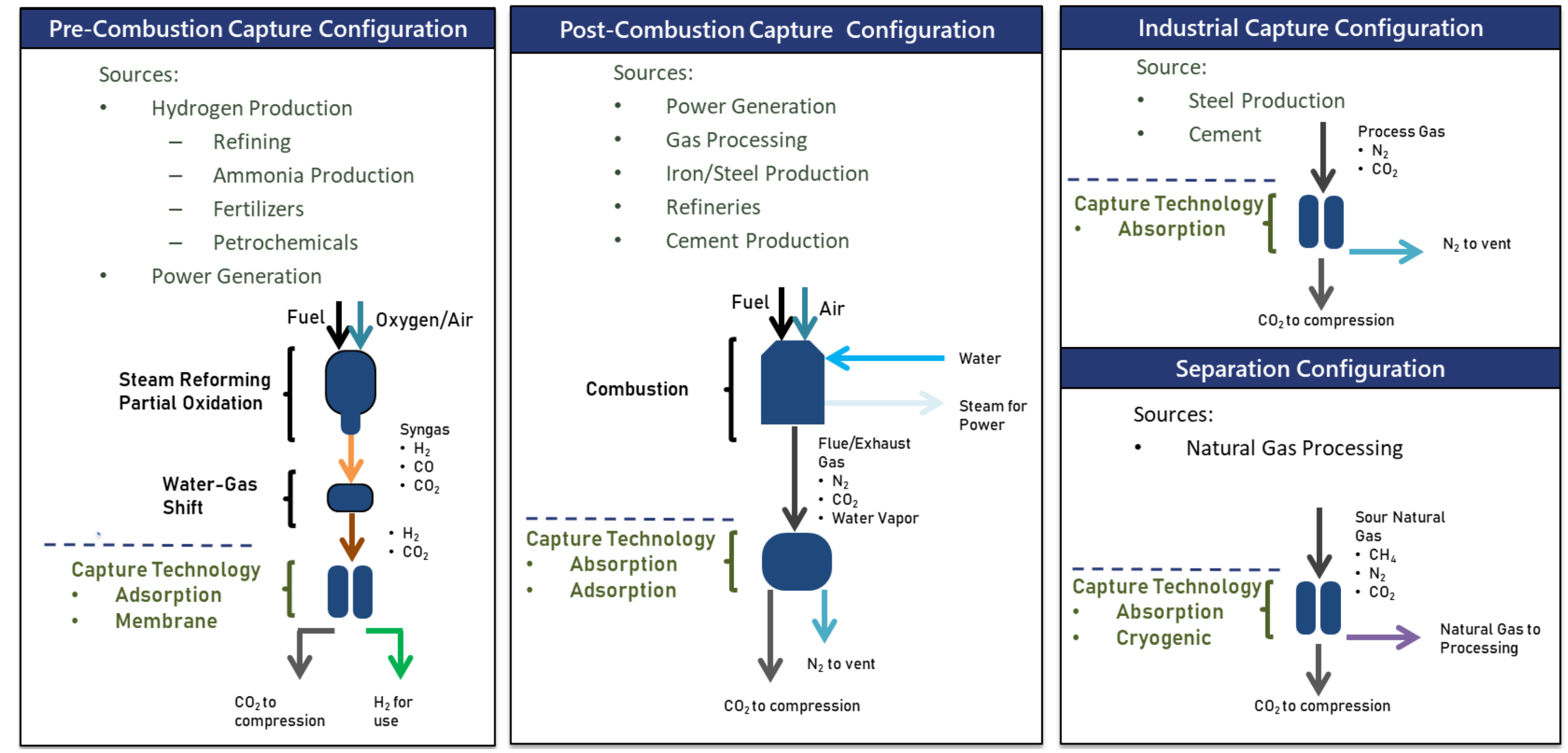


Figure 2.0: CO2 Capture: Configurations and Typical Associated Technology

The capture configurations are as follows:

- **Pre-combustion** is normally utilized during hydrogen-generation processes that include steam reforming or partial oxidation. Because of the high volumes of hydrogen generated, pre-combustion capture can be tied to refining, ammonia and fertilizer production and petrochemical manufacturing.
- **Post-combustion** makes use of a capture unit located after the combustion process. It separates CO_2 from a flue gas stream, as in the earlier example.
- **Industrial processes** generate CO_2 through the manufacturing chemistry. Steel and cement production emit significant amounts of CO_2 as a direct result of process chemical reactions.
- **Separation capture** removes CO_2 from reservoir gas streams.

  The most common configurations in use today are pre-combustion and separation, mostly because of hydrogen manufacturing in ammonia and fertilizer production and gas processing when reservoir CO_2 concentrations are high.

The major capture technologies are as follows:

- **Absorption** is the most commercially mature carbon capture technology and consists of a liquid solvent, usually amine-based, which selectively absorbs CO_2 out of a gas stream in an absorber column. Recent advancements in absorption have focused on optimizing the solvent or process configuration.
- **Adsorption** is commonly used in conjunction with the pre-combustion configuration and uses a solid sorbent instead of a liquid solvent. CO_2 is adsorbed onto the sorbent packing in a column until saturation, where the sorbent is regenerated by manipulating the column temperature (Temperature Swing Adsorption (TSA) or pressure (Pressure Swing Adsorption (PSA). The latest advancements in adsorption have focused on improving the sorbent material and shape of the packing.
- In **membrane separation**, a thin membrane selectively lets certain gas species (the permeate) across, while the remainder of the gas cannot cross the membrane (retentate). Membrane separation is promising based on startups and pilot plants with small-scale success, but has not yet been proven to scale-up.
- Finally, **cryogenic separation** is a physical process that manipulates stream temperature to remove CO_2. Cryogenic separation has only been attempted at a pilot scale. With no upscaling or technical advancements, the technology remains non-commercial.

Depending on the distance of capture-to-market location and volumetric requirements, CO_2 can be transported in

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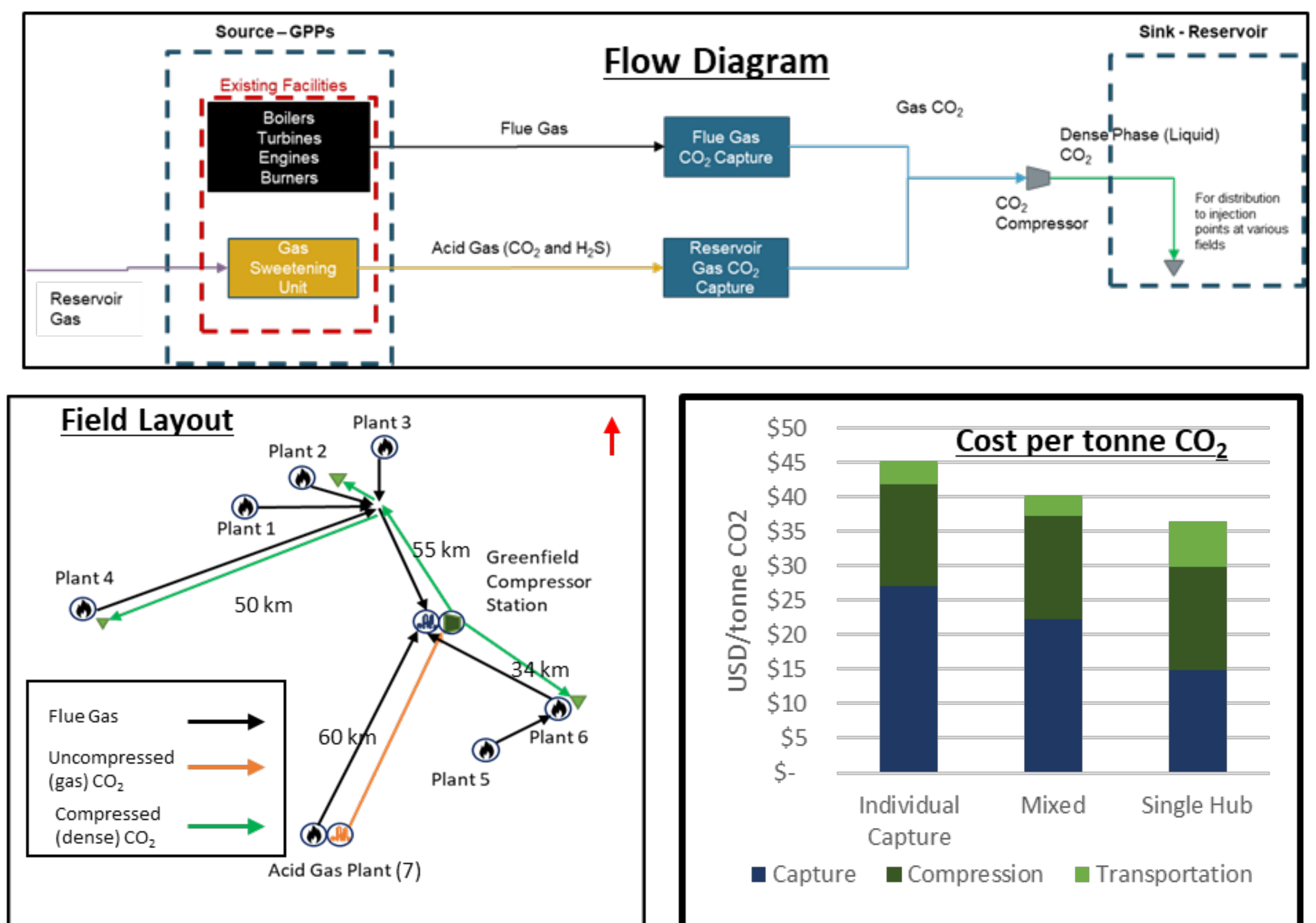
different physical states. In the gas phase, CO_2 has lower density, and higher capacities that require larger pipeline diameters. For instance, Kinder Morgan transports CO_2 in gas phase from basins in Colorado to the Permian requiring relatively large-diameter pipelines. Supercritical and dense phase CO_2 exhibit higher densities closer to those of liquids so more CO_2 can be transported with a smaller diameter pipeline. However, high pressures are required to achieve supercritical or dense phase CO_2, thereby requiring additional compression and greater pipe-wall thickness. Further compression to injection pressures can require significant energy: the back end of a high-pressure compressor can reach 3,500 psi. Design considerations influence initial CAPEX requirements, and include a number of compressor stages and a dehydration package. The energy requirements to operate the compressors dictate OPEX, which is typically higher for low CAPEX. As always, tradeoffs must be studied to arrive at an optimal cost for the compression segment of the value chain.

As of 2018, only 5,000 miles of CO_2 pipelines existed worldwide and we anticipate the CO_2 midstream market will increase rapidly in the near future to accommodate the requirements of large-scale CCUS. Repurposing of existing oil and gas pipelines rather than constructing new CO_2 pipelines is a possibility to reduce cost. When comparing CO_2 pipelines to oil and gas pipelines, key differences stand out. CO_2 forms carbonic acid in the presence of water, which is highly corrosive to steel. Therefore, it is necessary to dehydrate the CO_2 stream to high purity using a TEG (tri-ethylene glycol) system before it enters the pipeline. Internal corrosion protection is used depending on the pipeline design life and CO_2 purity. It is also important to maintain operating conditions within a certain pressure and temperature to prevent phase transition.

Injection of CO_2 began commercially in 1972 and is considered technically mature. CO_2 requires corrosion-resistant materials in various well components. For example, piping, valves and wellheads may require Stainless Steel 316 for corrosion resistance. Tubing requires Glass Reinforced Epoxy (GRE)-lined carbon steel, Internally Plastic Coated (IPC) carbon steel or another Corrosion Resistant Alloy (CRA). Additionally, a supercritical pump may be required to pressurize the CO_2 to injection pressure, or miscibility pressure if EOR is considered.

In addition to being utilized for EOR, CO_2 can be stored for long-term sequestration in depleted oil and gas reservoirs or deep saline formations. Most long-term storage projects today inject CO_2 into saline formations, but many planned projects in the near future will store CO_2 in depleted oil and gas fields. The depleted fields must be evaluated for CO_2 storage capacity considering pressure requirements, potential leakage pathways, reservoir integrity and the optimal configuration of injection wells. Finally, storage requires a robust monitoring, reporting and verification (MRV) plan per 40 CFR 98.440 from the U.S. EPA.

Figure 3.0: Regional Development



For storage capacity certification, the SPE approved the CO_2 Storage Resources Management System (SRMS) in 2017.

Besides optimizing each value chain segment, we reviewed potential capture concepts for multiple natural gas processing plants located in a region shown in Figure 3.0 on opposite page.

The development includes seven (7) plants that process more than 10 Bscfd of natural gas, with one processing acid gas with a significantly higher H_2S and CO_2 content. The compressed CO_2 is then distributed back to the fields for EOR. In the development, one extreme is an individual capture case for each gas processing facility with its own carbon capture plant getting CO_2 from the flue gas generated from onsite power as well as an individual compressor station. At the other extreme is a single hub wherein all CO_2 from the flue gas is captured at one central location, with the exception of the acid gas plant, which transports a pure stream of gas-phase CO_2 to the central compressor station. A single hub is significantly cheaper at $36/tonne CO_2 compared to $44/tonne CO_2 for the individual capture. Within that range, the company considered numerous cases of mixed hubs for a phased approach to reduce the initial capital expenditure.

This case study proves that taking advantage of economy of scale and phasing development are effective ways to make a CCUS project economical. It also shows the importance of applying the hub concept to capture, compress and transport CO_2 to various locations for EOR. This conclusion applies equally to regional collaborative CO_2 storage hubs.

Figure 4.0 summarizes breakeven price reduction avenues we have discussed in both case studies.

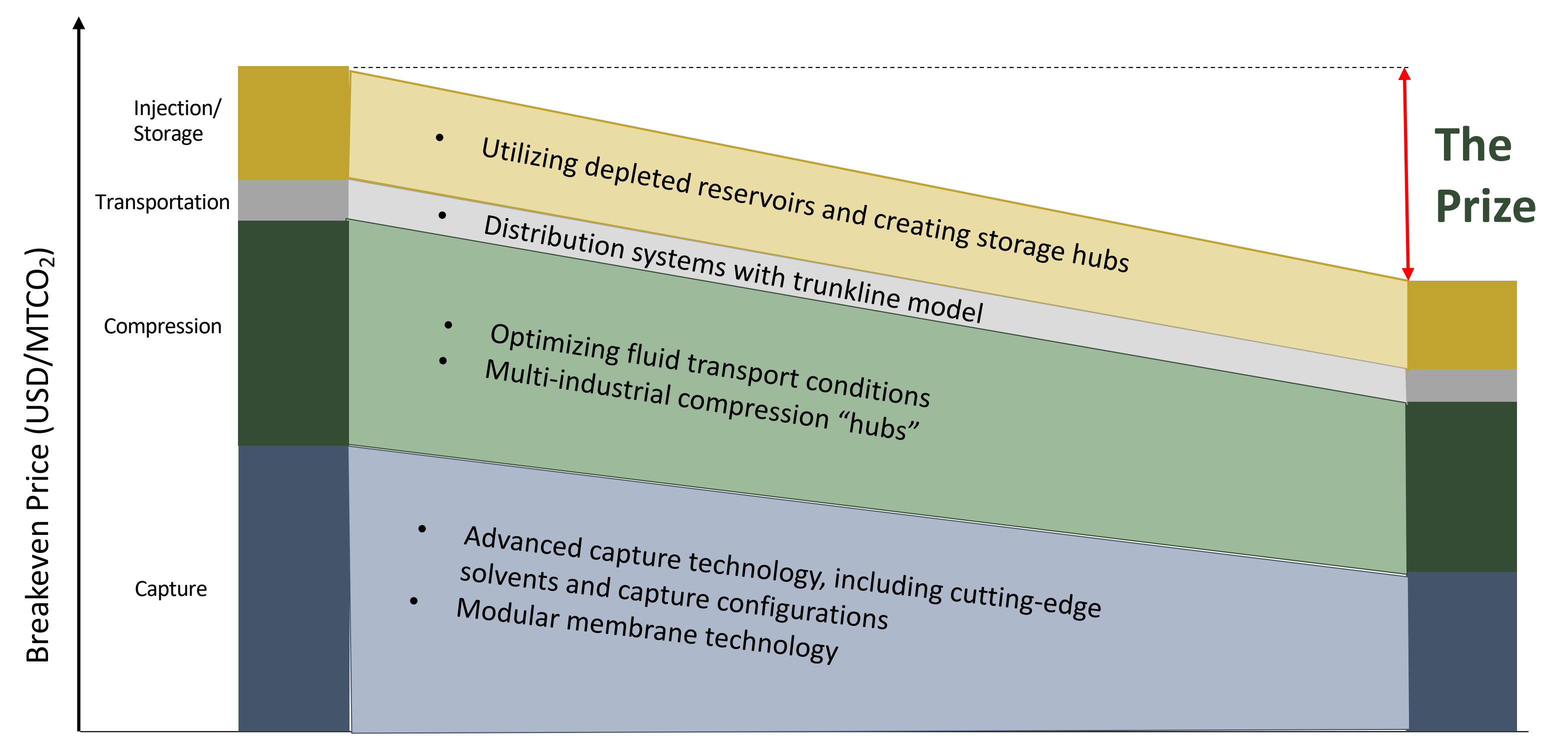


Figure 4.0: Breakeven Price Reduction

Restating the opportunities to reduce the breakeven price are as follows:

- For injection and storage, identify and select formations to create strategic storage hubs with optimal injection plans to reduce costs.
- For transportation, the biggest way to reduce costs is to optimize pipeline lengths or operating conditions, or to use a trunkline model. Alberta Carbon Pipeline has done the latter with an operating facility that gathers carbon from a couple of different facilities and transports it in one pipeline (trunkline) downstream for injection.
- For compression, opportunities to reduce costs are evident in hubs, commercial and public/private partnerships and optimization of fluid transport conditions.

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Reservoir engineering expertise important in CCUS projects

Miles Palke

Miles Palke, managing senior vice president at Ryder Scott, presented "Greenhouse Gas — The Role of the Petroleum Engineering Consultant," at a July 15 company-sponsored webinar over Zoom.

He discussed the subsurface aspects of carbon capture, use and storage (CCUS); what a traditional reservoir engineering firm can provide; and how CCUS fits in with the Ryder Scott sustainable energy consulting practice.

Palke said that the Ryder Scott CCUS subsurface services include the expertise of drilling engineering for well design and cost estimates, engineering for completion design and stimulation and production engineering for vertical and inflow performance. Ryder Scott offers a nodal analysis package to clients that can be helpful for vertical flow.

Palke cited the firm's strength in evaluating and designing field development plans to enhance oil recovery through miscible CO_2 floods.

This includes estimating reserves, evaluating reservoir performance and infill drilling results, reviewing surface facility design for CO_2 re-injection compression projects, optimizing CO_2 flood management and calculating cash-flow economics.

Ryder Scott has evaluated most of the Permian Basin CO_2 floods.

"A lot of fields don't have prior histories of CO_2 flooding, so we have to bring in analogs," he said. "We have a big database of existing CO_2 floods we've studied and have dimensionless curves built for this. This can be done pattern-by-pattern or on a larger basis."

"We also have a strong background in natural gas storage. This is the process of using older reservoirs to hold natural gas produced in other places, and to withdraw the gas at required rates for peak shaving or seasonal needs," said Palke.

Ryder Scott underground gas storage services share technical features of potential GHG sequestration projects. Underground storage can include salt-mined caverns or porous media, such as retired oil and gas fields and aquifers. Ryder Scott assists clients in developing gas storage reservoirs through the use of reservoir simulation.

On subsurface gas storage projects, he stressed analysis of injection well construction, including metallurgical issues, and vertical well performance curves.

"We have to look at what it's going to take to make wells that can withstand the pressures required to inject gas at the required rates into the storage reservoirs," said Palke.

Understanding the inflow performance of injectors for a given bottomhole pressure and how much gas can be injected at what rate are key issues to tackle.

"There may be potential issues with containment of injected GHGs in subsurface media, which can be porous sandstone or carbonate, salt caverns or depleted oil reservoirs," said Palke.

Other subsurface factors include aquifer displacement and integrity and size of the trap. An effective trapping mechanism is necessary to prevent upward migration of oil and gas or GHGs through the reservoir rock.

Palke cited PVT properties of GHGs and miscibility pressure. "Gas injection has to reach a certain pressure to achieve a full EOR benefit. Mixing other gases with CO_2, such as separator gases from the field, will change miscibility and effectiveness. Not only will it change how the injectant reacts with in-situ fluids, it will change how much CO_2 is ultimately stored in the reservoir," he said.

Palke pointed out that tax credits and any EOR benefit can make or break project economics.

Ryder Scott has several geoscience tools and combines those with PVT analysis and material balance to estimate the size of the "tank," and more importantly, to assess the soundness and integrity of the reservoir.

The reservoir engineering approaches ensure that CO_2 stays in the ground and does not migrate out of the known accumulation.

Palke said the reservoir simulation group has full capabilities for each reservoir engineering tool cited in the chart below, including compositional reservoir simulation.

Ryder Scott CCUS Subsurface Services

Keeping CO_2 in the Subsurface

- Total Reservoir Engineering Approach inclusive of:
  - PVT Analysis
  - SCAL Analysis
  - PTA/RTA for Estimation of Reservoir Properties
  - Volumetric Analysis
  - Material Balance Analysis
  - Analytical Performance Modeling for Enhanced Oil Performance Estimation
  - Compositional Reservoir Simulation

A compositional reservoir simulator calculates the PVT properties of oil and gas phases once they are fitted to an equation of state (EOS). The simulator uses the fitted EOS equation to predict movement of the phases, and their compositions, in the reservoir.

"How many wells? What is the development planning process? You'll have to build it around a certain volume to be handled on an annual or other time basis," said Palke. "You're going to need to know how many wells it will take to get those volumes in the ground within the required time frame as well as some sort of contingency on top of that."

Ryder Scott uses pressure-transient analysis (PTA) and rate-time analysis (RTA) to estimate permeability and mobility, which in turn, provide answers on what injection rates to expect.

"Typically, when we're looking at the enhanced recovery benefit from a CO_2 flood, we're looking at dimensionless recovery curves that plot a tertiary recovery factor of oil vs. CO_2 or other gas injectants," said Palke. "We like to look at the prior performance of the reservoir, analyze how it's performing under CO_2 flooding to get a sense of performance and then build a dimensionless curve that will project it going forward."

Ryder Scott generated the model below that shows a reservoir used for gas storage. It was originally a gas discovery produced down until it was depleted and then the reservoir was converted to gas storage by injecting a working storage volume of gas into it.

"This is an interesting problem because the reservoir simulation showed the original gas accumulation in this high area in red. However, the reservoir actually has a fault separating it from an upthrown fault block in blue and that fault dies out to the south," he said.

Over injection cycles, gas had been pushed down to a spill point (where the green meets the blue.)

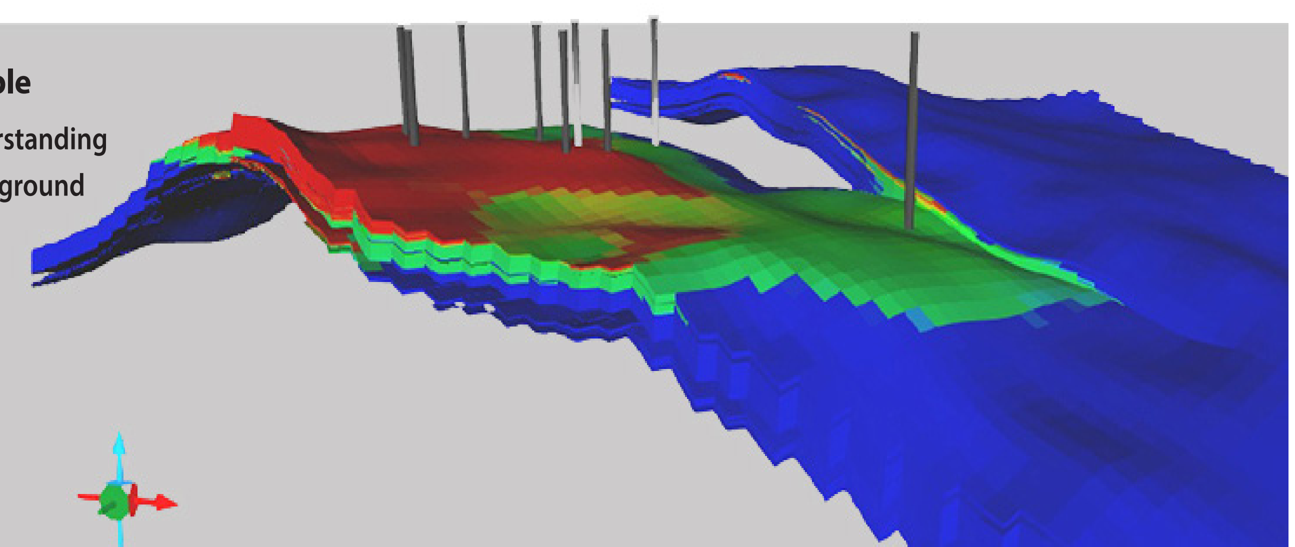
"Everywhere you see color is gas that has migrated out of the original location of the gas accumulation. The simulation model was helpful to demonstrate what migration had happened in the past. The example shows a typical kind of problem when storing gas in the subsurface in a gas-saturated phase," said Palke.

If the trap has any faults/flaws, the simulation can calculate how much gas has been lost and how much would probably be lost in future storage cycles for optional development scenarios.

For more information, please contact Palke at miles_palke@ryderscott.com.

Gas Storage Example

Developing and understanding performance of underground storage is best accomplished with reservoir simulation.



Two reservoir engineers join Ryder Scott


Freddy Alvarado

Freddy Alvarado and **Carlos Alvarez** joined the Ryder Scott Houston office recently, bringing with them more than a half century of combined reservoir engineering experience at IOCs, NOCs and service companies.

Alvarado is a senior petroleum engineer with more than 20 years of diverse experience in reservoir engineering and economic analysis. His competencies include nodal analysis, integrated production modeling, material balance and production analysis and forecasting.

Most recently, Alvarado was a senior reservoir consultant with Miller and Lents Ltd. He evaluated reserves and analyzed the economics of U.S. and international projects. Alvarado also audited the reserves of deepwater projects in the Gulf of Mexico and provided technical advice to the operator. He implemented tools to evaluate production-sharing agreements.

Before that, Alvarado worked at Chevron Corp. starting in 2015, as a reserves advisor and intellectual property manager. He provided petroleum reserves quality assurance, oversaw reserves bookings in the Trinidad, Colombia, Brazil Venezuela, and Argentina units, and ensured reserves alignment with the corporate reserves group.

Alvarado was also a reserves coordinator at Chevron Saudi Arabia. He supervised reserves evaluations for carbonate and sandstone fields in Saudi Arabia and Kuwait, and ensured reserves compliance. He streamlined the reserves booking process to better coordinate efforts between the business unit and corporate reserves group. Alvarado also formed steamflood-booking strategies.

Before that, he was a chemical EOR project manager at Chevron Corp. starting in 2011. He designed chemical-enhanced oil recovery processes and was the subsurface lead for IOR/EOR evaluations of Latin American assets. His work involved calculating recovery factors, forecasting production and conducting numerical analysis for properties in South America.

Alvarado also worked at BP Plc. in Houston as a reservoir engineer for seven years beginning in 2004. He designed and delivered new technologies, including Bright Water in polymer flooding and Losal in EOR miscible gas and CO2 flooding.

Alvarado also conducted thermal/compositional simulations to design pilot options for several Venezuelan heavy oil fields in the Cerro Negro area of the Orinoco Belt.

He started his career at Pennsylvania State University, as a teaching assistant, and at Universidad Central de Venezuela, Caracas, as an instructor.

Alvarado has a BS degree in petroleum engineering from the Universidad Central de Venezuela, and MS and PhD degrees from Penn State.


Carlos Alvarez

Alvarez is a senior reservoir engineer with more than 30 years of diverse experience in that discipline. He specializes in EOR and IOR processes, and has taught numerous courses in this field.

Alvarez has evaluated and optimized oilfield development plans in Venezuela, Mexico, Norway and the U.S.

Before joining Ryder Scott, he worked at Gaffney, Cline & Assoc. for nine years as a principal advisor and project manager. Alvarez was a team lead for projects in the Gulf of Mexico, Mexico, Colombia, Trinidad, Suriname, offshore Brazil, Bolivia and Argentina.

He also evaluated the technical feasibility of production technologies for field development projects, including those in IOR/EOR/polymer, steam and CO_2 injection.

Before that, Alvarez was a senior reservoir engineer in Mexico at Baker Hughes Reservoir Development Services. He provided reservoir engineering analysis to support corporate exploration-and-development activities.

Alvarez was an IOR /EOR advisor for reservoir development at PDVSA Intevep in Venezuela during 2005 to 2010. He helped establish standard methodologies for pilot test design of thermal and chemical IOR methods in Venezuela oil fields. The project also included evaluation of the technical and economic feasibility of new technologies for improving oil production.

Alvarez coordinated multidisciplinary teams to evaluate oil fields in the Orinoco Oil Belt, Lake Maracaibo and north of Monagas in Venezuela. He collaborated in integrated reservoir studies for various oil fields. The components of those studies included analysis of potential implementation of IOR projects inside current development plans.

Alvarez also conducted analytical modeling and performance evaluations, including decline-curve analysis, material balance and other methods. He was also a technical project manager for the first pilot test of the WAG process in Lake Maracaibo.

Before that, Alvarez was the IOR advisor for reservoir development in PDVSA east and west divisions for heavy and extra heavy oil at Lake Maracaibo and the Orinoco Belt, starting in 1990. He was also an invited consultant for the Rogaland Research Group in Norway for a technology transfer program in IOR technologies between Venezuela and Norway.

Alvarez has a BS degree in mechanical engineering from the Universidad del Zulia in Venezuela and an MBA degree from the Universidad Catolica Andres Bello in Venezuela. He is a member of the European Association of Geoscientists and Engineers, SPEE and SPE.

Please see Third-party assurance of ESG – Cont. from page 2

rate those standards into our regulatory regime," said Commissioner **Elad L. Roisman** at the SEC last June. "While this approach seems expedient and responsive to concerns about expertise, we have to acknowledge that this is not a 'plug and play' solution."

He compared a standard-setter in ESG to FASB which sets accounting guidelines for the SEC, and cited "a fear about the (FASB) standard-setter's independence and credibility being compromised by its funding sources and proximity to the industry it regulates."

Roisman acknowledged that the Sarbanes-Oxley Act mostly resolved those funding issues when it required companies to pay accounting support fees.

"Questions persist about FASB's independence from market participants," he said.

Oneness in nature – Cont. from page 3

financial funds, with monthly payouts, experience an organic exponential decrease. The Internet makes use of an exponential-decay model to decrease routing failures (flapping) on the World Wide Web.

Using radioactive decay as an example, the basic formula is as follows: N is the size of a population of radioactive atoms at a given time t, and dN is the population decrease in time dt. Rate of change is generated by the equation, $dN/dt = -\lambda N$, where λ is the decay constant.

The simple, yet powerful equation models decays and associated declines that change the world in big and small ways.

Carbon Capture, Utilization and Sequestration – Cont. from page 9

- In capture, the biggest opportunity to reduce costs per tonne of carbon is in the technology, which includes optimizing the solvent or configuration or using a technology that hasn't necessarily been proven at a commercial scale, but has been relatively successful on a pilot scale.

In addition to cost reduction opportunities, policy continues to increase the price of carbon to improve revenue. Policy instruments like carbon taxes and tax credits, e.g. 45Q, allow tax offset opportunities to maximize profits from a primary revenue stream, such as the sale of oil or power. Emission trading systems (ETS) allow companies to trade emission allowances, typically in units of tonnes of CO_2, which provide a revenue source directly generated from storing carbon. The number and magnitude of these policy instruments have steadily increased and are expected to increase more rapidly in the future.

In conclusion, the two main components to increase commerciality are reducing costs and increasing revenue. Innovative solutions are formed using appropriate contracting and commercial models generated via a deep comprehension of CCUS value chain components, technology, designs, project configurations and risks and coupling them with carbon-credit incentives.

Ryder Scott is focused on technologies for capture, compression and transportation. This is useful to clients that want to understand a new technology marketed by a startup and how to contextualize that in a larger CCUS market. The firm's geologists, geophysicists and reservoir engineers are highly competent when assessing formations and utilizing carbon for EOR or long-term storage. Ryder Scott monetization strategies focus on incremental oil recovery from EOR, tax credits and emission-allowance benefits from long-term storage. Ryder Scott also offers verification and validation of emissions to help navigate the complex regulatory standards in reporting.

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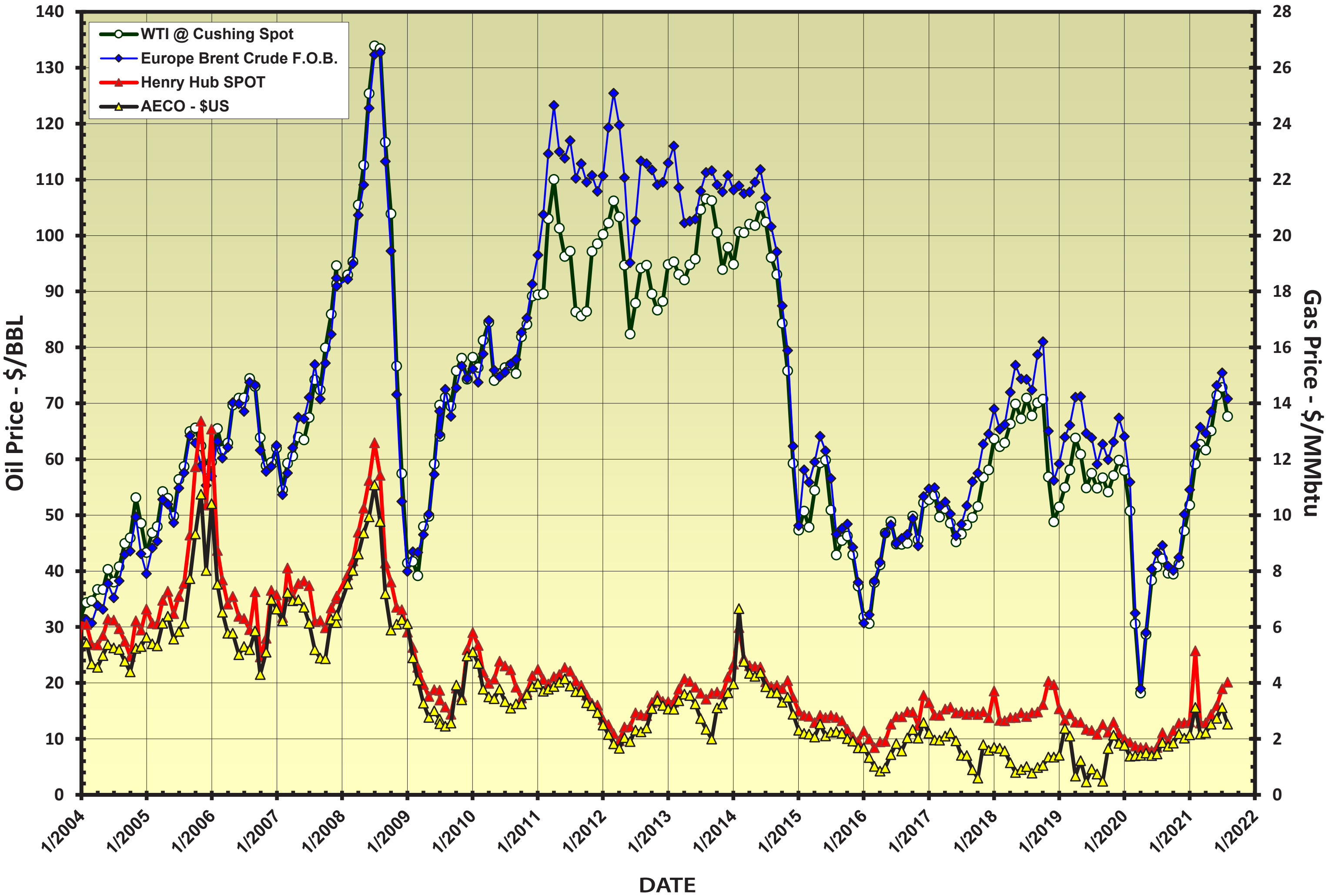
Price History of Oil & Gas Benchmarks in U.S. Dollars



Published, monthly-average, cash market prices for WTI crude at Cushing (NYMEX), Brent crude and Henry Hub and AECO gas.

Publisher's Statement

Reservoir Solutions newsletter is published quarterly by Ryder Scott Co. LP. Established in 1937, the reservoir evaluation consulting firm performs hundreds of oil and gas reserves studies a year. Ryder Scott multi-disciplinary studies incorporate geophysics, petrophysics, geology, petroleum engineering, reservoir simulation and economics. With 125 employees, including 80 engineers and geoscientists, Ryder Scott has the capability to complete the largest, most complex reservoir evaluation projects in a timely manner.

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