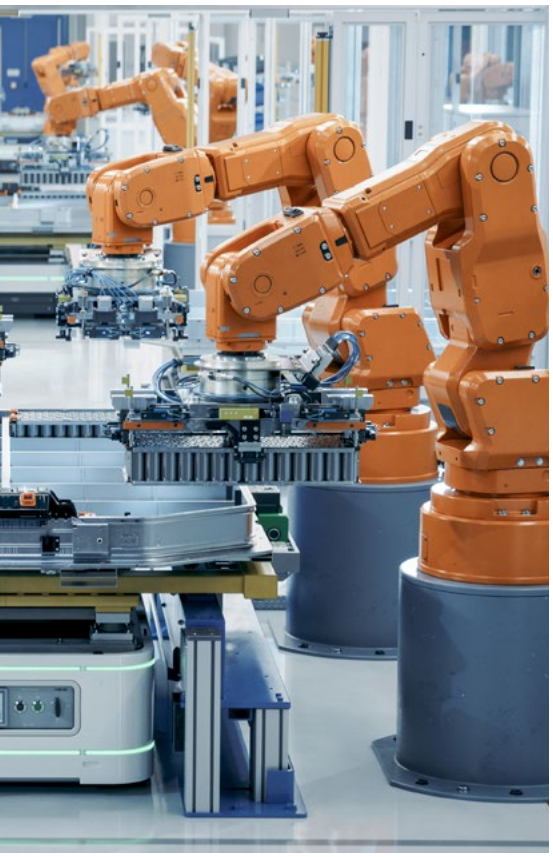
Direct lithium extraction from oil and gas production – An initial assessment

From waste to resource – DLE could yield essential battery metal and clean water



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S&P Global
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Initial DLE assessment of US oil and gas formations

Lithium, a primary battery metal essential for electric vehicles, electric-grid battery storage systems and portable electronics, is expected to be in short supply globally by 2028, but S&P Global Commodity Insights Upstream researchers say a new potential pathway to extract lithium from produced oilfield water could be an avenue to derive more lithium supply and a means to monetize an otherwise burdensome, costly, waste byproduct.

S&P Global Commodity Insights researchers say the potential to extract lithium from oilfield brines using a process called direct lithium extraction (DLE), is in its infancy, and many technological and economic hurdles must first be overcome to achieve benefit. Regardless, DLE is generating increasing industry interest due to the potential benefits.

S&P Global Commodity Insights estimates the oil and gas industry will generate more than 217 million barrels of water per day in 2024 from its upstream operations. At present, almost all this water is discharged, reinjected, or recycled, with only 8% yielding any form of economic benefit to operators. Produced water management is a costly, resource-intensive endeavor, from treatment to transport, and ultimately storage or reuse.

"The potential to capture additional valuable resources such as lithium and potable water that is suitable for agricultural use from the vast volumes of wastewater generated from the oil or gas production effort is very attractive to operators," said Prithiraj Chungkham, director, Unconventional Resource and lead geologist at S&P Global Commodity Insights.

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Most promising US geologic formations for DLE

Intrigued by this potential, Chungkham conducted a brief, early assessment of potential US geologic formations that could yield economic levels of lithium via direct lithium extraction from produced water.

"The use of DLE could provide additional revenue streams for what has traditionally been an expensive industry burden and growing sustainability obligation, and it is drawing significant industry interest," Chungkham said. "Our initial assessment is focused on identifying the most likely US formations for DLE based on certain geologic and geophysical criteria combined with initial well analysis to identify a focused subset of wells that contain baseline lithium concentrations."

Chungkham's preliminary assessment of potential formations for DLE extraction targeted US geologic formations with producing wells that delivered an estimated baseline volume of 50 milligrams (mg) lithium per produced liter of water. Since reporting of produced water chemistries is not required in the US, Chungkham started his analysis by examining a dataset of nearly 10,000 wells from the **US Geological Survey (USGS) Produced Water Geochemical Database v 2.3,** which contained formation water (brine) and geochemical data, including lithium and bromine concentrations.

Chungkham then combined those wells with data and analysis from the ***S&P Global Commodity Insights US Gulf Coast Onshore Kingdom Geologic Project*** that he and his team recently published, to assess for certain geologic and geophysical traits, including penetrated volcanics.

According to Chungkham, his initial S&P Global Commodity Insights DLE assessment indicates approximately 60 possible US formations could yield the minimum baseline of 50 mg of lithium per liter of produced water that Chungkham estimates would be needed to potentially make DLE economic.

Potential US formations for direct lithium extraction

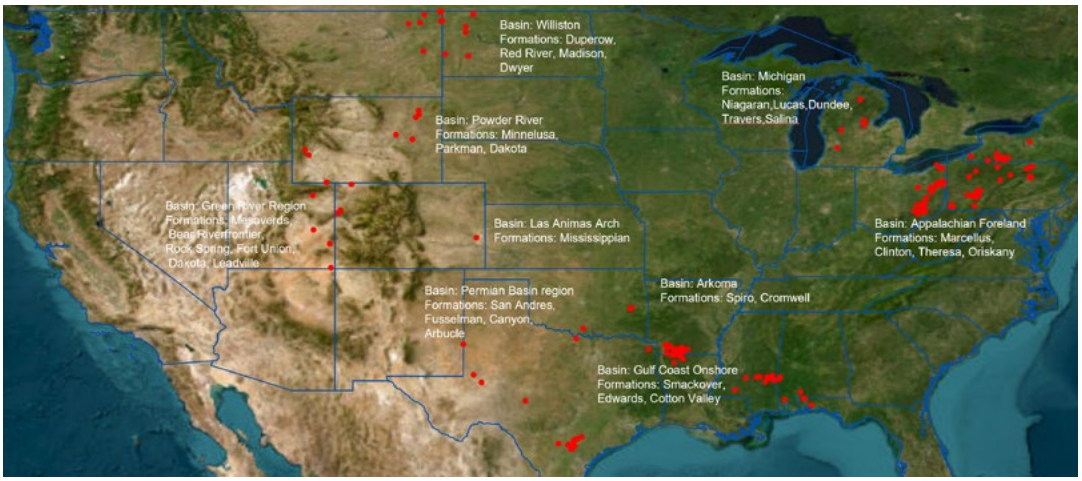


Fig1. Map showing distribution of wells with lithium content equal to or greater than 50 mg/L in the formation-water analysis data. Source: Courtesy USGS Produced Water Geochemical Database v 2.3.

"Using our vast US S&P Global historical database of well and production data, we were able to estimate how much water has been produced from the wells in the identified formations and to determine how much water remains in those formations that could yield lithium," Chungkham said. "That knowledge allowed us to do some initial resource assessments regarding potential lithium recovery from those formations and targeted subsets of wells."

Depending on the economics, he said it is also likely that companies will re-enter abandoned wells that had a very high water cut and were otherwise uneconomic. Operators may also drill wells specially designed to better access the brine.

"DLE is attractive because the potential additional profit is not pocket change for operators, particularly when water management is an added cost that currently dilutes their profit margins," Chungkham said.

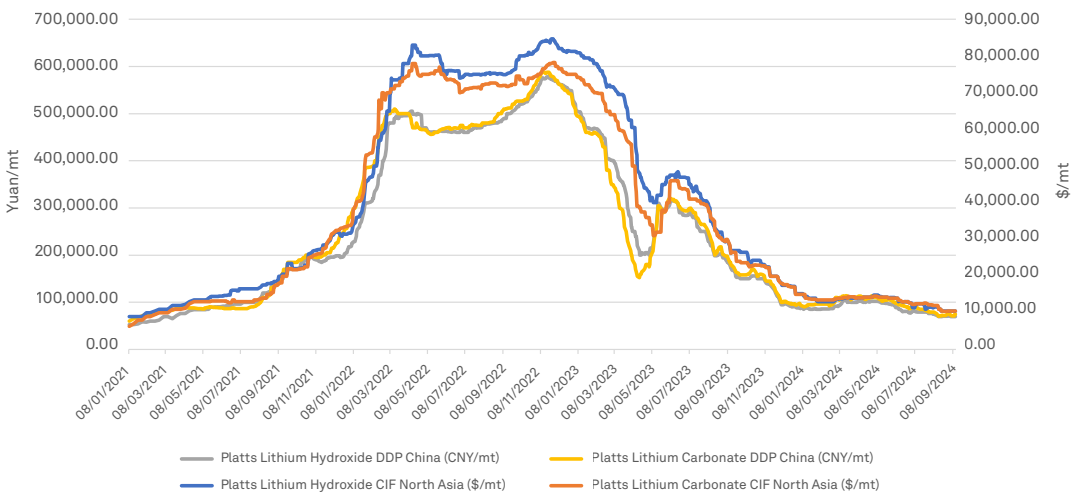
While the S&P Global Commodity Insights first-look DLE analysis was focused on identifying core formations and wells with the most potential for DLE recovery, Chungkham said widespread adoption and economic viability, however, will require ongoing technological advances.

Lithium prices lower on supply growth, slowing growth in demand

According to S&P Global Commodity Insights, lithium chemical supply is forecasted to be 1,218,000 metric tons (mt) lithium-carbonate-equivalent (LCE) in 2024. Commodity Insights forecasts this will be met by chemical demand of 1,106,000 mt LCE in 2024, up from 704,000 mt in 2022, and an estimated 868,000 mt in 2023.

"The lithium market is currently oversupplied because EV sales have slowed more than expected while there is more supply coming to market based on investment decisions made when prices were high," said Alice Yu, principal analyst, Metals and Mining, S&P Global Commodity Insights. "We are confident in the long-term EV and lithium demand trajectory and that the lithium sector will return to a market deficit by 2028, reflecting challenges in supply keeping pace with demand growth, despite oilfield brine sources beginning to ramp up operations on that timeframe."

Platts lithium salts assessments have seen unprecedented volatility over the past four years



According to S&P Global, lithium prices have experienced significant volatility in recent years, with the market currently in oversupply and prices depressed. However, S&P Global analysts expect demand to increase, with lithium in a supply deficit in 2028.

Inadequate lithium supply could impede EV production and the energy transition, so automakers are eager to see a greater diversity of regional supply, S&P Global said. Tesla and others have gotten involved in securing direct sources of lithium supply to ensure they can meet future production requirements.

Yu is forecasting an average lithium carbonate CIF North Asia price of about $12,500 per tonne, far below the $70,000/t and $40,000/t averages in 2022 and 2023, respectively. The fall in prices could hinder development of DLE in oilfield brines, and has also caused miners to start cutting back on production, given that Yu expects the 90th percentile cost for 2024 to come in above $14,000/t for traditional hardrock mines.

Lithium production pathways

Lithium is conventionally extracted from hardrock deposits and continental brines. DLE technology is being considered for continental brines to shorten the production time. At present, production takes around 13-16 months due to the time it takes to concentrate lithium-carrying brines by evaporation in a succession of man-made ponds, after the brine is pumped to the surface. This process is time consuming and climate dependent.

DLE technology also also being applied to extract lithium from more novel sources, including oilfield brines, geothermal brines, and clay deposits. These novel deposits types are found in the US and developing them could make the country more self-sufficient in lithium.

Bringing a new lithium mine online takes on average 17 years from discovery to production, according to S&P Global Commodity Insights' proprietary research. The timeline could be much longer for new deposits requiring new processes. Low lithium prices currently could also significantly slow project developments. However, in the long run, new domestic lithium projects would still be an investment worth making to unlock the vast lithium potential in the U.S.

Some tout DLE as 'holy grail' for lithium production, but experts caution success not yet proven

According to Yu, the second generation of lithium projects is expected to bring new kinds of assets that were never developed before, such as clay, oilfield, and geothermal brines, as well as the potential deployment of direct lithium extraction. While some people see DLE as a possible 'holy grail' for lithium production, Yu cautions that the technology must still be proven commercially.

"Many of the projects using these newer technologies to extract lithium from the novel deposit types are planning to produce lithium chemicals that are more readily usable in downstream battery cathode manufacturing, but the projects will still need to prove their commercial viability first," Yu said. "DLE is not an off-the-shelf solution that can be applied the same way in all projects, each brine chemistry is unique and requires a tailored process and more testing is needed on a commercial scale."

Operators eager to see ExxonMobil's results from early direct lithium extraction in Smackover formation

ExxonMobil, however, hopes to change that. In the US, ExxonMobil is actively engaged in testing the potential for direct lithium extraction, Chungkham said, with its activity focused on the company's Smackover formation located in southwest Arkansas.

"The world is watching and waiting to see what ExxonMobil delivers from its DLE project in the Smackover," Chungkham said. "However, there is also a concern amongst oil and gas industry leaders that they don't want to wait too long to gain an understanding of the potential for DLE, as the formations that offer promise could be highly desirable assets."

"The world is watching and waiting to see what ExxonMobil delivers from its DLE project in the Smackover."

Operators and service companies investing in lithium extraction

Other operators and technology companies are also investing early in DLE. Amid a flurry of industry activity in this direction, Commodity Insights notes two technology developments announced during the first quarter of 2024 that exemplify overall industry efforts: a partnership between **Halliburton Co.** and technology startup **XtraLit Ltd.,** and **Occidental Petroleum Corp.'s** $15 million investment in technology startup **Pure Lithium Corp**.

These announcements highlight a few interesting developments in the industry's pursuit of commercializing produced water via DLE technology, including:

Growing oil industry interest. Commodity Insights recorded only two DLE technology development and commercialization announcements prior to 2022 targeting oil and gas produced water, but that figure jumped to 19 between 2022 and the first quarter of 2024. While 40% of this activity involves technology startups, another 40% is being driven directly by global oil and gas operators (e.g., **Equinor ASA, Eureka Resources LLC, Exxon Mobil Corp.**) and oilfield services companies (e.g., **Schlumberger Ltd. (now known as SLB**).

SLB announced in a Sept. 10, 2024, news release that it has proven its solution for sustainable lithium production at scale at its demonstration plant in Clayton Valley, Nevada, to accelerate bringing responsibly sourced lithium products to market.

The company said its proprietary integrated solution combines SLB's subsurface expertise with surface engineering of advanced technologies that include direct lithium extraction. According to SLB, the process produces lithium 500 times faster than conventional methods while using only 10 percent of the land. Operating at approximately one-tenth the size of a commercial-scale facility, the plant reached a verified recovery rate[1] of 96% lithium from brine.

SLB says its integrated solution is a complete, end-to-end process that includes advanced impurity treatment and concentration technologies to produce high-purity lithium carbonate or hydroxide. The solution also uses significantly less water, energy and fewer chemical reagents in comparison to other DLE-based offerings.

Shifting innovation models. Commodity Insights analysis reveals that DLE technology development and deployment models are largely shifting from direct involvement activities (e.g., internal research and pilot projects) to increasing investments in technology companies and projects.

"This change to a more collaborative, project-based model is likely driven by recent government actions that are encouraging companies to accelerate their pursuit of such opportunities," said Aditi Goel, senior analyst, Upstream Research, S&P Global Commodity Insights, who co-authored an upstream technology brief on DLE with Oscar Abbink, director, Upstream research. "To accelerate progress and reduce project risk and cost, it makes sense to invest in companies already active and in projects already underway—it is likely a more efficient way to growth than organic, solo efforts."

Innovation focusing on lower concentration oilfield brines. While produced oil and gas water contains valuable minerals and metals, their low concentrations often do not justify the costs associated with traditional extraction methods (i.e., evaporation). DLE is an emerging technology that appears to offer advantages over these traditional methods (e.g., faster production and higher recovery rates), and Commodity Insights currently tracks 18 companies (mostly technology startups) actively developing solutions in this area.

China's oversized influence drives desire for supply diversification

Lithium supply security has become a top priority for technology and automotive companies in the U.S., Europe and Asia, and as a strategic energy resource priority for many governments. Government leaders are aware their industrial sectors are increasingly dependent upon a group of essential minerals and metals to produce vital electronic and battery dependent products and to compete globally.

According to Commodity Insights, China controls more than 70% of global lithium refining. The country has clear leadership in upgrading lithium resources into battery quality material. The looming shortage of lithium supply cast amidst growing demand as EV adoption escalates, is driving market desire for greater supply diversification and regionalization for those metals.

(Read more about the key narratives and trends across the critical minerals spectrum and our market forecasts in the inaugural edition of the ***S&P Global Commodity Insights' Critical Minerals Briefing quarterly report.***)

To counter this growing critical resource imbalance and ensure a reliable, diversified, and affordable supply of lithium, the U.S. government is addressing the need to secure supply, with a focus on incentivizing domestic development. This includes not just mining or DLE, but investment in refining, since most lithium produced must currently be sent abroad for further refining.

This lack of refining capacity means much of the product's value is not captured domestically, and the supply chain remains highly dependent upon other countries such as China for the necessary processing—an uncomfortable dependency, experts say.

Oil and gas sector accustomed to solving technical challenges like DLE

Despite this lack of commerciality for DLE at present, Chungkham says the fact that brine production for lithium extraction is already a necessary step in many lithium projects, oil and gas operators in the US have a strong incentive to extract more value from produced water, and the sector is well known for solving complex technical challenges.

"The US unconventional oil and gas industry evolved to what it is today because technological innovators were able to leverage highly pressurized water to fracture what was once considered worthless shale rock and extract hydrocarbons economically," Chungkham said. "The results propelled the US to a new era of oil and gas competitiveness and its status as a global leader in production. Now unconventional producers have the potential to extract more benefits from that water and turn a waste product into something valuable. This is a challenge they are well accustomed to solving, so the future of DLE could be exciting for the US oil and gas industry."

S&P Global Commodity Insights considering further DLE studies

Chungkham said his team is considering a more in-depth study of the potential for DLE, that would include discussion on extraction technologies, engineering challenges, production and economic scenarios and forecasts.

"Wherever formation water geochemistry data are available, we can readily estimate lithium resources for formations and provide geological components such as structure, isopach, tops, etc. for all the basins we have covered in our S&P Global Commodity Insights Kingdom Projects," Chungkham said.

Those available S&P Global Commodity Insights Kingdom-derived geologic projects currently include:

- The Gulf Coast Onshore Basin (US)
- The Permian Basin (US)
- The Greater Anardako Basin (US)
- The Powder River Basin (US)
- The Alberta Basin (Canada), to be completed in second or third quarter 2025.

Kingdom Geological Studies deliver 3D geological models for key basins, identifying productive formations and estimating resource volumes, including: original-in-place and technically recoverable resources.

> "... US producers are well accustomed to solving technical challenges, so the future of DLE could be exciting for the US oil and gas industry."

For more information on the following offerings from S&P Global Commodity Insights:

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