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GreenSpace Tech
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# Direct lithium extraction

Revolutionary potential still to be proven in the field

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*Lithium is known as a "critical mineral." A crucial ingredient in batteries for consumer electronics, laptop computers, and electric vehicles (EVs), demand for the mineral is expected to soar in the coming decades. Current lithium production methods may have trouble keeping up, but a promising new production method known as Direct Lithium Extraction (DLE) might help fill the gap. While not yet proven at scale, DLE is being nurtured by significant private and public investment and multiple pilot projects. To help manage risk, stakeholders in the lithium value chain may wish to consider spreading bets across the DLE ecosystem.*

Lithium is a mineral crucial to the energy transition.[1] The International Energy Agency (IEA) projects lithium demand, driven by EV batteries and other energy storage, could soar to nearly 700 kilotons in 2030, eight times the 84 kilotons sought in 2021.[2] But while demand surges, supply will likely lag.

Despite the anticipated expansion of lithium mining and processing, supply may only cover two-thirds of demand in 2030.[3] At the same time, traditional ways of extracting lithium from rocks or brine cannot be scaled easily to meet demand. Challenges include uncertain or long project lead times, as much as 7-8 years, for brine projects to reach production.[4] Also, lithium recovery rates from brine can be as low as 40%.[5] Further, traditional methods are energy- and water-intensive, polluting, and use vast tracts of land causing biodiversity loss.[6]

## Direct lithium extraction may overcome challenges associated with traditional methods

An emerging family of techniques known as direct lithium extraction (DLE) promises to be faster, more productive, and more environmentally responsible.[7] Traditionally, brine is held in ponds to evaporate the water and the residue is processed for lithium. DLE encompasses multiple techniques that separate lithium from brine using chemicals or materials that bond with lithium ions. It can deliver consistent yields, unaffected by weather and other conditions that can impact evaporation. Further, without the need for ponds, DLE can shrink land use by nearly 95%. It can also reduce water use and cut production time to hours or days from the months or years required for evaporation, while boosting lithium recovery rates from 40%-60% to 70%-90% or higher.[8] Given these potential benefits, DLE appears to be finding favor in national lithium strategies, such as in Bolivia and Chile.[9]

Table 1 summarizes common DLE technologies. Deloitte GreenSpace research of 38 DLE innovators and vendors and 57 lithium production projects using DLE shows that adsorption is the most adopted. It is simple and efficient, has a high lithium recovery rate, and accommodates low lithium concentration brines.[10] Meanwhile, an analysis of DLE-related patents show that innovation continues in known DLE methods, such as new or better adsorbents and ion exchange membranes.[11] DLE is also diversifying. For instance, an innovator is developing “DLE for hard rock”—a carbon dioxide-based method to extract lithium from spodumene ore that an investor says is faster, 50% cheaper, and 90% less water-consuming than traditional methods.[12]

## Table 1. Some major direct lithium extraction techniques

| Technique | Description [13] | Inferred technology readiness level | Process efficiency [14] | Lithium recovery rate [15] | Number of innovators or vendors | Number of DLE projects | Select challenges [16] |
|---|---|---|---|---|---|---|---|
| **Adsorption** | Adsorbent materials bind with and capture lithium ions from brine | 9 – commercial | >75% | 95%-99% | 16 of 38 | 27 of 57 | Higher operating temperature (>40ºC) and additional processing to extract lithium from sorbent |
| **Ion exchange** | Resins exchange lithium ions from brine with hydrogen ions. Washing resins with acid recovers lithium and restores hydrogen. | 7 – demonstration | - | 90%-99% | 6 of 38 | 8 of 57 | Large quantities of acid to recover lithium from resin |
| **Membrane separation** | Mixture of brine and other fluids is pumped through membranes that allow only lithium ions to pass | 7 – demonstration | >90% | 80%-99% | 7 of 38 | 3 of 57 | Mainly suits brine low in sodium or potassium and is relatively water-intensive (though more water efficient technology is in development) |
| **Solvent extraction** | Solvent chemicals react with brine to form lithium compounds that deliver lithium with further processing | 6 – prototype | 60%-90% | 85%-97% | 4 of 38 | 3 of 57 | Solvent poses environmental and equipment corrosion challenges |
| **Precipitants** | Reagents added to brine make lithium precipitate in crystals | 3 – conceptual | >90% | 90%-99% | - | - | Can precipitate unwanted minerals creating reagent loss and waste disposal challenges |
| **Electrochemical separation** | Electricity passed through lithium solution makes lithium ions migrate to an electrode | 3 – conceptual | - | - | - | - | Energy-intensive, poor durability of materials used, and suits lithium refining than extraction |

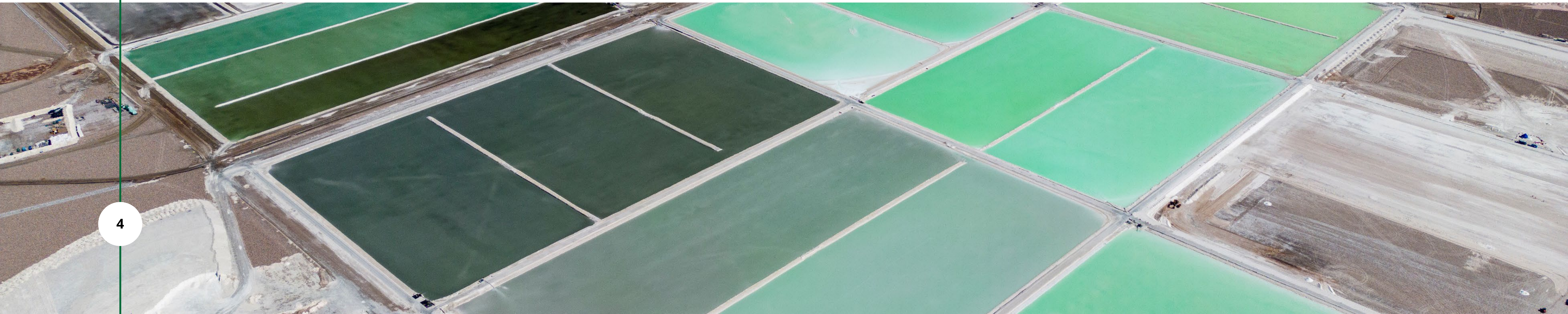
**Note**

- Technology readiness level (TRL) inferred via Deloitte GreenSpace analysis and comparison against IEA's TRL definitions [17]
- Innovator and project data was captured from secondary sources through June 12, 2023, and is not exhaustive
- DLE technology for six of 38 innovators/vendors and 16 of 57 projects is unclarified, undisclosed, not finalized, or other

**Source:** Deloitte analysis based on Butt et al. (2022), DLE company websites, Goldman Sachs, news articles, Stringfellow and Dobson (2021), and TDK Ventures

## Public and private sector investments indicate interest

Since 2020, DLE innovators have received more than US$979 million in investment.[18] DLE-based production projects are also attracting funding from governments and private entities. For instance, the United States (US) Department of Energy (DOE) provided a US$50 million grant to an ion exchange DLE startup in 2022.[19] And foreign state-owned entities intend to invest US$1.5 billion in two Bolivian DLE projects.[20] Among private investors, notably, multiple automakers have funded DLE players and contracted lithium supply from them.[21] Other private funding highlights include a miner acquiring an Argentinian DLE project for US$825 million and a commodities trader investing US$252 million in a US-based project in 2022.[22]



## Investors should better understand the capital requirements of large-scale production

DLE remains experimental, though, with only a few technologies proven in the field. For instance, there are two startups with membrane and ion exchange technologies piloted in the field.[23] Together, they have attracted US$690 million of the nearly US$1 billion funding for DLE vendors since 2020.[24] Beyond pilots, DLE is being used commercially in one project in Argentina that leverages adsorption to extract small amounts. [25]

High costs may be a barrier to scaling production via DLE. Goldman Sachs finds upfront capital expenses for DLE projects can be in the range of US$300-$900 million compared to US$200-$500 million for traditional brine evaporation.[26] This is due mainly to the equipment involved, which may need to be customized based on brine composition, further escalating expenses.[27] Brine conditions vary and not all DLE techniques suit all brines.[28]

In the long run, DLE's higher capex may be offset by lower unit costs given greater lithium recovery rates.[29] Also, consumables such as reagents or sorbents and electricity are large components of DLE operating expenses. Research is ongoing to make consumables more durable, cheaper, and able to extract more lithium. Further, in some regions, producers can tap geothermal brine and help drive DLE with geothermal power.[30]

## An ecosystem approach may mitigate risks

The DLE ecosystem is dynamic and diverse. Deloitte GreenSpace research found more than three dozen DLE technology innovators and vendors, many of which were founded in the last three years. There are also more than 50 lithium producers looking to adopt DLE in projects spanning at least 12 countries, mostly in the US, Argentina, and China.[31] The players include government research labs, universities, and enterprises from the automotive, chemicals and industrial equipment, mining and metals, oil and gas, and power sectors.[32] They can often have distinct and complementary needs and capabilities (see Table 2). This suggests opportunities for collaboration.

## Table 2. Ecosystem segments, needs, and potential contributions

| Ecosystem segment | Segment needs | Segment potential contributions |
|---|---|---|
| Mining and minerals | • Capital<br>• Improved sustainability profile<br>• Improved project economics | • Mining knowledge |
| Chemicals and industrial equipment | • New market for offerings | • Sorbents and other DLE consumables |
| Oil and gas | • New markets<br>• Improved sustainability profile | • Materials and process knowledge such as drilling for geothermal brine<br>• Capital |
| Engineering, procurement, and construction | • New markets | • Process design capabilities<br>• Project implementation services |
| Battery and automotive | • Stable lithium supply<br>• Improved sustainability profile | • Stable lithium demand<br>• Capital |
| Power utilities | • Clean energy storage | • Geothermal energy knowledge<br>• Capital |
| Researcher, such as universities or government laboratories | • Capital<br>• Alignment with mission | • Technical insights and innovation |

**Note:** Ecosystem segments and their needs and potential contributions are indicative and not exhaustive

**Source:** Deloitte GreenSpace Research

In Utah, for example, minerals company Compass Minerals plans to use adsorption DLE technology developed by EnergySource Minerals along with existing evaporation ponds to produce lithium for a US-based automaker and a battery manufacturer LG Energy, with a conglomerate investing US$252 million to fund the project.[33] Similarly, in a project in Arkansas, a chemical company is providing the site, brine, and other infrastructure, while partner Standard Lithium provides its ion exchange DLE technology. Standard Lithium owns the project through the feasibility study phase. Post-study, the chemical company may acquire a portion of the project and some or all lithium. The same conglomerate is also an investor in Standard Lithium.[34]

Companies with an interest in lithium may find it beneficial to consider cultivating an ecosystem of collaborators. This could present opportunities to help mitigate the technical and commercial risks of investing in DLE while creating new paths to expanding the supply of a critical mineral.

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