TB AMATI STRATEGIC METALS FUND

Amati Site Visit Series

VULCAN ENERGY
ZERO CARBON LITHIUM™

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VUL.ASX - A TB Amati Strategic Metals Fund Portfolio Company

Direct Lithium is key to the future of lithium production in our view. Investing in this area of lithium production is very complicated, but the potential investment returns could be large, if a company successfully commercializes the process.

Direct Lithium Extraction (DLE) describes a group of emerging process technologies that selectively removes lithium from a brine to produce a concentrated lithium solution. The concentrate can then be refined into various lithium compounds dependent on requirements. This compares to current lithium production processes that focus on pre-enrichment from a primary source (evaporation in brines or spodumene concentration) and then refining/separation from gangue (brine refining or spodumene conversion). In both stages energy and reagents are consumed to concentrate and refine, and waste is generated.

DLE-based methods, seek to preferentially extract lithium with impurities remaining in the 'spent' brine and reinjected into the aquifer.

DLE is not a 'new' technology, but rather the application of well-established hydrometallurgical processes to processing of lithium. Against conventional processing, advantages of DLE include:

• improved economics of exploiting lower grade/higher impurity lithium resources;

• lower reagent consumption;

• reduced fresh-water consumption;

• significantly shorter production lead times (vs typical 12-18 month residence times in evaporation ponds); and

• smaller physical footprint (i.e. no evaporation ponds, waste disposal).

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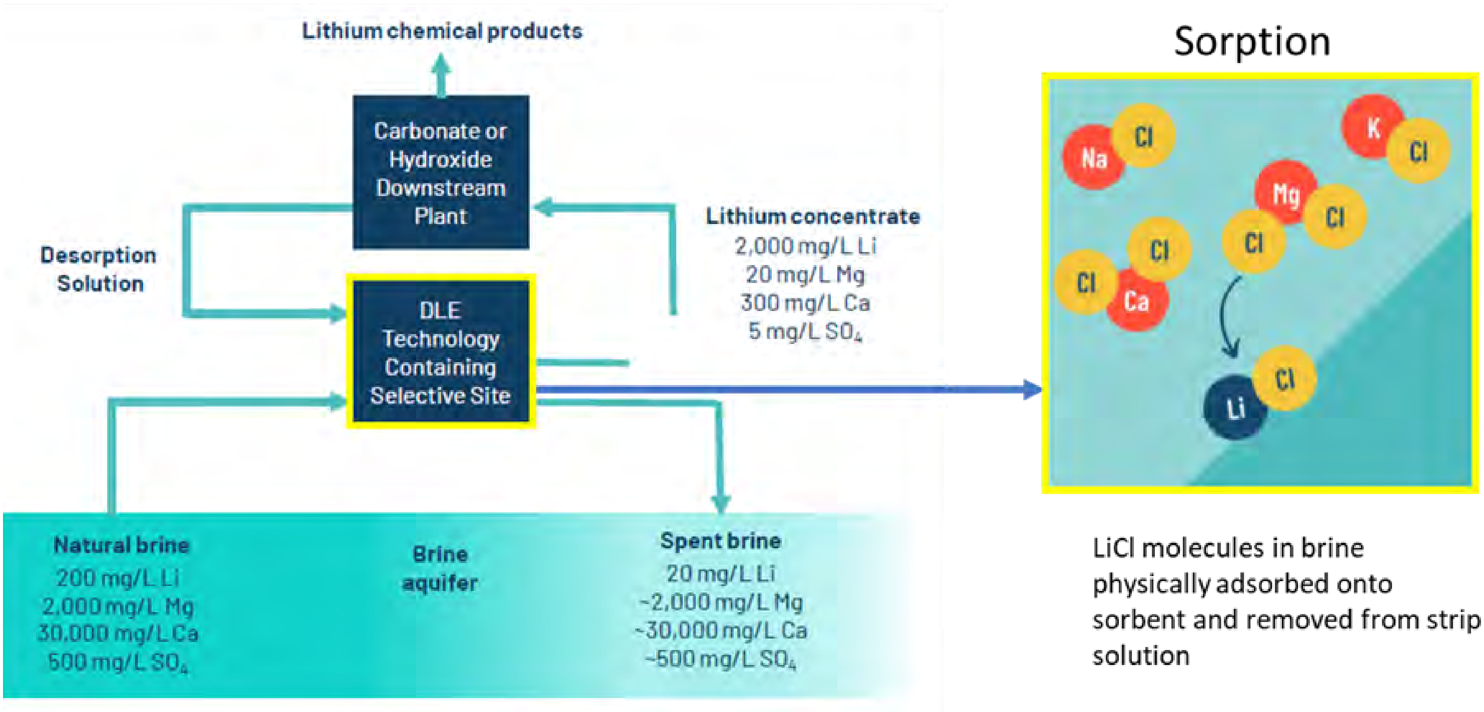
Figure 1 - Schematic of a generalised DLE process



Source: Vulcan Energy, Amati

Vulcan is developing the Zero Carbon Lithium project in the Upper Rhine Valley, Germany. The project proposes to use an innovative approach, extracting hot brines to generate geothermal power, then using DLE (adsorption) and electrolysis to produce battery-quality lithium hydroxide. VUL has secured offtake for its first five years of production through Volkswagen, Stellantis, Renault, Umicore and LG Energy Systems demonstrating strong levels of confidence in VUL's approach. Furthermore, VUL signed an offtake with German city of Manheim for heat, increasing alignment with the local government.

The 40ktpa lithium hydroxide and 73MW geothermal energy project hosts the largest lithium resource in Europe and on our estimates is expected to achieve first quartile operational costs around (US$3,250/t). As the name suggests, VUL expects the project to generate no CO2 in LiOH production, differentiating it in the global market. We expect first production in 2026 and at nameplate capacity estimate VUL will generate annual EBITDA of over A$1bn.

The production of zero carbon lithium will involve a 4 step process, outlined in Figure 2;

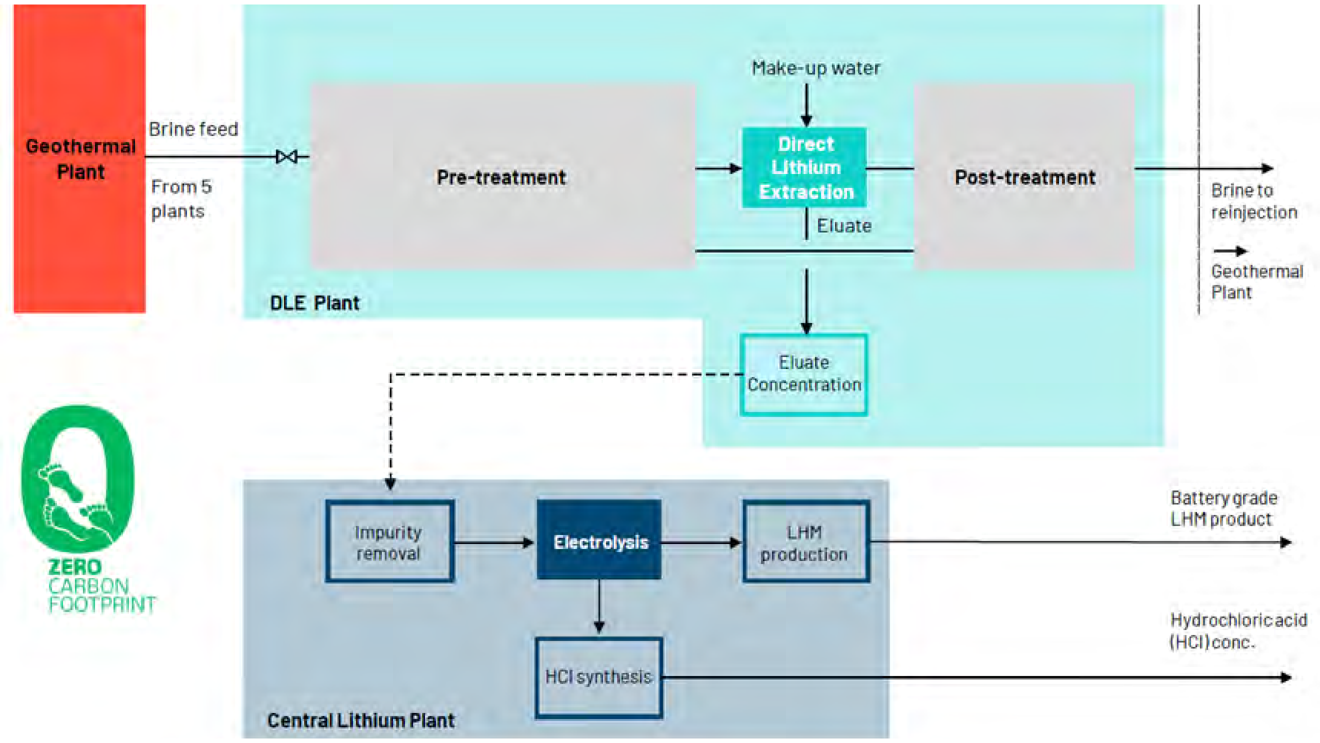
1. A geothermal brine will provide the in solution lithium feedstock and the source of power (Figure 3).

2. A sorption plant will recover lithium from the brine; sorption technology is commercially used for decades, with sorption technologies commercially available from several suppliers. Lithium recoveries could average 94-95%. Vulcan are piloting on live brines, operating 24/7 for the last 15 months (Figure 5).

3. A central lithium plant (CLP) will convert lithium chloride to lithium hydroxide using an electrolysis process. Electrolysis has been used by the chlor-alkali industry (Nobian) in a similar process for more than 100 years. Vulcan are in JV with Nobian to construct and operate the CLP. A 5kg/hr demo plant is planned for Q3 2023 (similar layout to Figure 6).

4. First samples of battery quality lithium hydroxide produced have been sent to OEMs and battery manufacturers. Binding offtake contracts have been signed for commercial volumes.

Figure 2 – Process Flow Sheet (4 step process)



Source: Vulcan Energy

Vulcan acquired NatürLich in Insheim in Dec 2021 (Figure 3). The geothermal plant can produce up to 4.8MW power (8000 homes) or 28.5MW thermal energy. Vulcan are aiming to upgrade the plant capacity and increase brine flow rates to consider lithium extraction from the brine. The current Indicated Mineral Resource of 0.7Mt Lithium Carbonate Equivalent @181 mg/l Li has been delineated at this site with 2 production wells. This is effectively a commercial R&D centre.

Figure 3: Geothermal Plant Natürlich Insheim

Source: Vulcan Energy

For commercial lithium extraction, the brine flow rates have to be around 100litres/sec. The above well flows at 70litres/sec, enough for pilot testing and R&D.

Figure 4: Geothermal production well (Amati fund manager for scale)

Source: Vulcan Energy

These wells go down over 1000m and the deeper the wells go, the higher the flow rates, temperature and lithium grade. Amazingly, the distance between the production well and reinjection well is 15m at surface, but over 1000m at depth, as the wells splay.

The Upper Rhine basin is uniquely positioned to provide renewable heat, high lithium grades and high brine flow rate potential. The graben structure of the Upper basin contains 15.85Mt of LCE (lithium carbonate equiv.), Europe's largest resource of lithium. The basin has 6 key attributes;

1. Concentration of lithium in the brine, av. 140-220mg/kg.
2. Permeability of the basin.
3. Size and volume of the basin.
4. Chemical composition of the brine, low in contaminants.
5. Temperature of the brine, allowing for renewable energy use and distribution, av. 5°C/100m depth.
6. Close proximity to the battery manufacturers and OEMs.

The Upper Rhine is a sedimentary graben system, geologically similar to hydrocarbon systems with permeable formations confined by impermeable rock. This differs to other types of geothermal plays, such as volcanic-hosted, where the systems are more complex, in general less permeable. Vulcan are using 3D seismic geophysical analysis of the basin to target high-flow fault zones within its sedimentary reservoir units. This should identify high brine flow rates from the geothermal reservoir.

Vulcan have been piloting (Pilot Plant 1) on live brines from the geothermal plant Natürlich at Insheim for the last 15 months (Figure 5). Consistent lithium concentrations have been achieved with low level of impurities. Lithium recovery rates are averaging 94-95%. Multiple sorbents from commercial providers have been successfully tested, including from DuPont and others, providing optionality.

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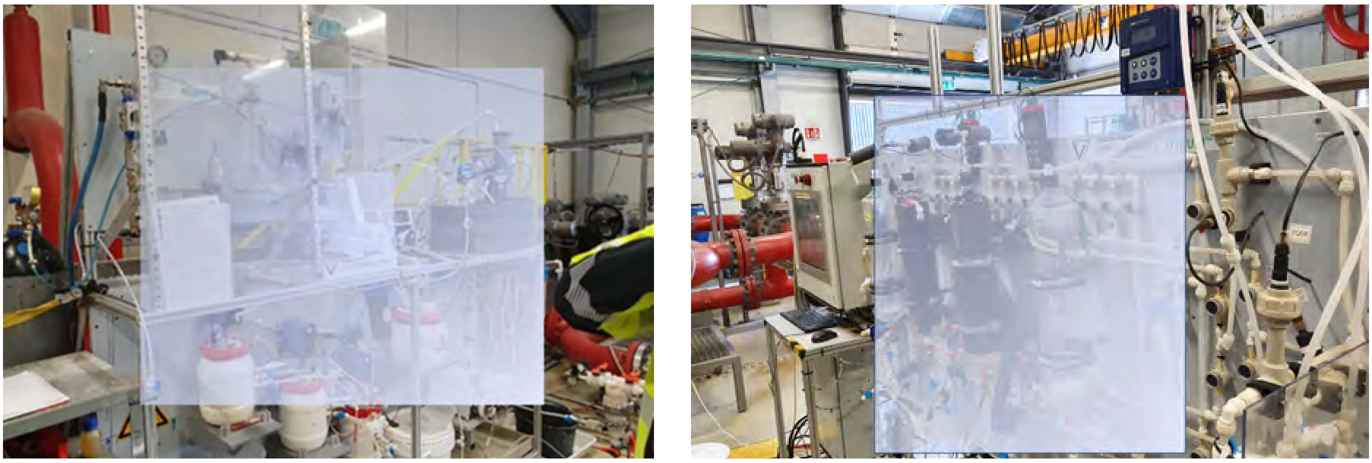
Figure 5: Pilot plant 1 - bench scale membrane sorption process



Source: Vulcan Energy

Note: Amati deliberately blurred the Membrane extraction circuit to protect IP

Vulcan are planning to develop a Demo Plant at the Industrial Chemical Park in Höchst, Frankfurt. This is one of Europe's largest chemical sites. The plant will be fully integrated with all process steps including electrolysis (similar to Figure 6). Sorption will occur at the same site with "live" geothermal brines. This demo plant will be approximately 1:200 scale of the first commercial plant, and a scale-up factor of 1:50 in terms of column size. This scale up is a critical step to demonstrate proof of concept from pilot to commercial status.

Figure 6: Bank of 8 electrolysers at Nobian's chemical facility, Höchst, Frankfurt

Source: Amati Global Investors

After visiting the Höchst Chemical plant, near Frankfurt, it became abundantly obvious that Direct Lithium Extraction requires a great deal of service and chemical infrastructure. Höchst hosts more than 22 ,000 personnel and 90 companies including Nobian, Clariant, Sanofi and Celanese. The CLP is intended as a processing hub, processing lithium chloride from multiple combined geothermal and lithium sorption plants into lithium hydroxide monohydrate. From the CLP, the lithium hydroxide monohydrate is intended to be transported to Vulcan's European customers in the battery and electric vehicle industry, dramatically lowering the transport footprint of the current lithium supply chain.

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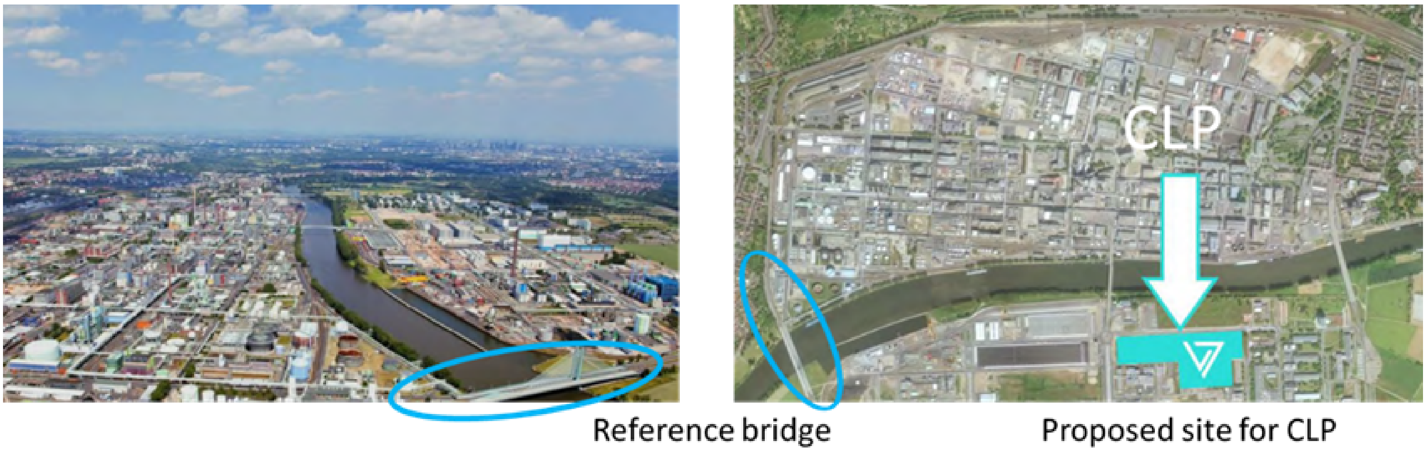
Figure 7: Höchst Chemical Plant and proposed site for the CLP



Source: Vulcan Energy, Amati

The challenge to meet the growing demand for lithium with a low carbon and environmental footprint is self-evident. The lead time from commissioning an electrolyte plant to steady state production can take up to 5 years.

With this in mind we don't see a supply wave coming from DLE in the short term, and expect lithium prices to remain high. The ASMF has around a 30% direct exposure to the lithium market through its investments in the lithium developers, producers and a royalty company. Screening these investments takes a deep understanding of the sector and certainly can't be done from the Bloomberg screen alone. I hope our first publication of the Amati Site Visit Series demonstrates the value add to visiting operations and development sites. More visit notes will come in due course.

Written by
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