After the DLE Cambrian Explosion

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Around two and a half years ago I started publishing articles on direct lithium extraction (DLE) technologies which could efficiently supply lithium to the battery industry. Now DLE is writing its own story.

From various different angles, I tried to share perspectives that DLE is interesting, important, and most executable natural resource projects that use new or updated DLE technologies should be first in line for finance and construction. Every 20,000 tonnes of lithium carbonate per year that can be produced through a small well represents an entire open pit that does not need to be quarried, and eliminates the local impacts that pits have on the people who live near them.[1] Due to the thermodynamic realities of producing lithium chemicals from solid minerals compared to salty waters, millions of tonnes of CO_2 emissions can potentially be avoided by unlocking more brine resources that were previously considered uneconomic because not enough people understood that there were ways to produce lithium chemicals from them.[2]

It became obvious to me over the last two years that investors from around the world were listening. In some cases, prospective projects and technology companies were able to raise money more effectively as DLE became better understood. On the other hand, like during any period of rapid growth in any industry ever, problematic players started to emerge from the woodwork to take advantage of the narrative.

The Cambrian Explosion

The last year saw significant progress of new DLE projects promising to add production capacity alongside existing commercial DLE operations in Argentina and China.[3] Eramet has decided to build their adsorption brine project in Argentina at Centenario, and Rio Tinto acquired Rincon Mining for $825M to take over their adsorption brine project, also in Argentina.[4,5]

A lot happened in 2021 in the junior project developer and startup space too. The technology startup Lilac Solutions raised $150M from T. Rowe Price, BMW, Sumitomo, Lowercarbon Capital, and Breakthrough Energy Ventures.[6] An oilfield brine project developer with assets in Arkansas and the U.S. Southwest named Standard Lithium raised $100M from Koch Strategic Platforms in November,[7] while a geothermal brine project developer named Vulcan Energy Resources raised almost $300M for their geothermal brine project in the Upper Rhine Valley of Germany.[8,9]

All of this activity is a product of a DLE technology "Cambrian Explosion" of the last 5-10 years. Dozens of new types of technologies and projects have emerged and some are reaching mid-stages of development. There is still a long way to go and plenty of issues can pop up along the way that could slow these projects, but there are at least a handful of them off to a good start.

So where does DLE go from here? If these projects don't produce significant quantities of lithium chemicals in the next five to seven years, then they should be considered failures. After the Cambrian Explosion, natural selection will guide DLE towards technology solutions which are most likely to flourish for both technical and commercial reasons. But how will investors, resource developers, and other stakeholders sort the good from the bad?

Natural Selection and Extinction

There is activity at the fringe which is concerning. For example, some junior mining companies reference successful DLE project developers' share prices to argue that their stock will increase in value simply because they are pursuing DLE. Comparisons like this immediately make me suspicious because resource projects can only succeed by being well executed in their own right.

Unfortunately, there are multiple private DLE technology startups presenting wildly overly promotional information about the products they are developing, such as giving the impression that they have a working prototype when in reality they are highly unlikely to ever be able to produce high-quality chemicals at large scale because the way they think their technology will work is not aligned with the laws of physics. I am watching this play out in multiple cases at the moment.

I feel a duty to help investors make wise decisions about DLE in order to minimize the amount of capital lost to unprospective projects and help the good ones get built. Below are some high-level guidelines for how to think about evaluating DLE technologies and projects based on my experience soaked to the bone in the space. I hope this helps minimize the number of major extinction events in DLE.

Team

The absolute most important feature of a DLE project is the team. Any company pursuing development of a DLE brine project has to build a real technical team of chemists, chemical engineers, and other technical experts who can help make these projects successful.

Any company saying that they will build a DLE project should employ multiple full-time engineers and ideally someone in a chief technology officer or VP Technology-type role. Exporting all of the hard work of piloting and process development to an external engineering company is not an option. That approach has caused multiple projects to lose years of progress and millions of dollars in recent history.

Technology Selection

Most of the advanced DLE projects are deploying technologies which are likely to work because they had to demonstrate their suitability for a particular brine resource in earlier development phases. This could mean demonstrating high recovery with high selectivity or the production of battery-quality lithium chemicals even at bench-scale.

I have found this to be both a low bar but an important one: it is relatively straightforward to make a chemical meet a specification at bench-scale with a good technology. But at least the bottom quartile of DLE technology solutions won't be able to pull it off. Production of bench-scale samples is a surprisingly relevant milestone despite the fact it does not come anywhere close to confirming that the technology will succeed in the long run. It confirms that the technology will "not not" succeed.

Different DLE technologies have different advantages and disadvantages. Some consume more reagents, some consume more energy, and some consume more (net) freshwater depending on the geochemistry of the brine.[10] Some could be built successfully in North America while some might end up being prohibitively expensive at 3,000 meters elevation in the Andes of Chile or Argentina.

The three main types of DLE are adsorption, ion exchange, and solvent extraction. They are fundamentally different, and different technology solutions within each category can be developed totally differently. The success of one does not entail the success of others.[11]

Energy, Water, and Infrastructure

Energy is required to make chemicals like lithium carbonate and lithium hydroxide monohydrate, but those chemicals don't need to be made at the same site as DLE. Various quantities of energy are required by different DLE technologies. Some legacy processes required the brine to be hot to function correctly,[12] but there are a number of new technologies which do not require this, meaning new projects may have much lower operating costs and CO_2 footprints.

It remains true that higher brine temperatures are beneficial for reducing costs for some technologies, providing an advantage for hot brines like geothermal and some oilfield brines. However, very hot brines like those at the Salton Sea have much more challenging geochemistry as more problematic elements like transition metals and silica tend to dissolve into the brine at higher concentrates because of the higher temperatures. In lower temperature geothermal brines, this can be less of an issue.

DLE projects which will require more heat or electricity than is available for a particular location are less likely to be successful than those that consume less since it could take years to build energy infrastructure to reach remote locations. There is one historical example of a brine project in Argentina planning to use more electricity than the entire province of Salta. That project did not progress, and instead restarted its process development exercise from scratch with better DLE technologies. Projects on brownfield sites or in places like North America or Europe where the grid is accessible can take advantage of better infrastructure to move faster.

Lithium is mostly extracted from the driest places in the world so there is often limited freshwater available for new projects. Water recycling is key to minimizing net freshwater consumption by these projects, and ensuring that as little additional freshwater is needed from nature as possible. Importantly, many of the new DLE projects will not require significant evaporation of water from brine in order to operate. This means that the risk of "invisible freshwater use" of aquifer interactions between mineralized brines and brackish or freshwater used by plants and animals which often sit on top of brines could be significantly reduced. Designing the subsurface strategy right may not always be straightforward though.

Brine Geochemistry and Hydrogeology

Legacy parameters for evaluating the quality of lithium brines like magnesium to lithium ratio are an artefact of an age when most people considered using chemicals and evaporation to purify and upgrade lithium chloride. They are not as relevant for most modern DLE technologies. For example, there are at least a dozen serious DLE projects developing brine assets which on average contain less than 500 mg/L of lithium, considered a rule of thumb minimum for development when only chemicals and evaporation were contemplated for process technology in the past. It is unlikely that brines containing 1-10 mg/L of lithium will underpin successful DLE projects as the cost of moving water becomes prohibitive, but brines containing 100-300 mg/L appear to be fair game based on recent progress by a number of projects.

Magnesium to lithium ratio of a brine was historically a critical parameter for evaluating the prospectiveness of brines. If this ratio was greater than around 7, the industry would not consider developing the brine when only chemicals and evaporation were considered as options. The reason is that magnesium can co-crystallize with lithium during advanced stages of evaporation, leading to lithium loss in waste salts. Instead of losing lithium, it is usually removed in evaporation ponds using lime. This drives operating cost and has CO_2 emissions associated with it as it is made from limestone, and every molecule of lime used has around two molecules of CO_2 in the atmosphere associated with its production. Today, there are at least a dozen DLE technologies which can produce lithium chemicals from brines containing magnesium to lithium ratios in the tens and even hundreds, such as the brines in Qinghai already producing commercial quantities.[3] Some DLE technologies cannot tolerate divalent ions like magnesium, but I would argue that these are not very good DLE technologies.

Geothermal and oilfield brines often contain tens of thousands of mg/L of calcium which was also historically considered an issue but is no longer a categorical issue. A great counter-example is the 3Q Lithium Project in Argentina, which suffers from a high calcium to lithium ratio, requiring use of extra energy and land in order to remove the calcium.[13] The operating cost and CO_2 emissions associated with this could have been avoided if the lithium was separated from the calcium by DLE. What a sad missed opportunity! Perhaps this is one reason why it seems only Chinese companies are acquiring lithium projects like 3Q while Western companies prefer projects that use less sloppy process technology.

Finally, hydrogeology is absolutely critical in developing DLE brine projects. Brine needs to be moved around from production to reinjection in such a way that fresh brine and spent brine will not mix too quickly.[14] Aquifers need to be large in order to enable significant long-term lithium production and reinjection. It could be possible to find a 1,000 mg/L lithium brine anywhere in the world, but if the aquifer is only 5 centimeters wide or if an impermeable clay hosted the brine, it would be impossible to produce brine fast enough from it for enough time to make it worthwhile. Sedimentary geologies tend to host larger and hydrogeologically simpler deposits, while fluids in cracks in granite rocks tend to hold smaller deposits despite the fact the grade can be high in those fractures. Brine needs to be able to flow quickly through the aquifer for a very long period of time with minimal dilution in order to produce enough lithium to make the project worthwhile.

Almost All Membrane Technologies Described as DLE Will Fail

If I had a gram of lithium hydroxide for every time a university intellectual property office reached out to me to ask if a membrane that one of their researchers developed will apply to lithium extraction from the ocean, I could build a Gigafactory.

For some reason, people think membranes are the greatest separation technology and I do not understand why. Different folks of different levels of technical insight propose to use membranes of different types to separate lithium from brines. It is my view that membranes applied directly to natural brines will almost all fail. The reason is that most brines are super-saturated, saturated, or near-saturated solutions of salt in water. When water is removed from the salts, the salts crystallize, coming out of solution as solids.

If lithium is separated from brine by permeation through a membrane and retention of all other salts on the feed side, then it means that the brine needs to be diluted by a factor of around 10 (not diluted 10%, but have its volume increased by a factor of 10) in order to recover 90% of the lithium and avoid supersaturation of the brine, leading to crystallization of salts and blocking of the membrane surface. This will almost always not be economic or feasible at least outside of China.

Please stop asking me about membranes. Please stop talking about membranes for DLE. Please stop investing in membranes for DLE. You are wasting people's time and money. Now it would be quite funny to be proven wrong on this after publishing this article. But based on my observations to date, I feel comfortable taking a strong position on this topic.

Conclusion

If a number of DLE projects are to be built in the 2020s, helping satisfy the demand for lithium created by the rapidly growing battery industry, then it is important that investors understand how to sort good from bad. Hopefully this article helps. The Cambrian Explosion of DLE technologies of the last decade has created a tremendous diversity of technology solutions. Some will succeed and some will fail. That is alright because a portfolio of approaches is needed to ensure that lithium chemicals can be produced fast enough to meet demand from the battery industry.

From here, the laws of natural selection take over in DLE. Let's see how they evolve!

Acknowledgements

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References

(1) Grant, A., 2021. Op-ed: Albemarle should build their Magnolia DLE project. URL.
(2) Grant, A., 2020. The CO_2 Impact of the 2020s' Battery Quality Lithium Hydroxide Supply Chain. URL.
(3) Grant, A., 2020. From Catamarca to Qinghai: The Commercial Scale Direct Lithium Extraction Operations. URL.
(4) Eramet, 2021. Eramet accelerates into the metals for the energy transition and engages the construction of its lithium plant in Argentina. URL.
(5) Rio Tinto, 2021. Rio Tinto to acquire Rincon Mining lithium project. URL.
(6) Lilac Solutions, 2021. Strategic Investors Join Final Closing of Lilac Solutions' $150 Million Series B for Lithium Extraction Technology. URL.
(7) Standard Lithium, 2021. Standard Lithium Completes US$100 Million Direct Investment From Koch Strategic Platforms. URL.
(8) S&P Global, 2021. Vulcan Energy secures A$120M to fund Zero Carbon Lithium project in Germany. URL.
(9) Australian Financial Review, 2021. Vulcan Energy in $200m placement; Goldman, Canaccord on board. URL.
(10) Stringfellow, 2021. Technology for the Recovery of Lithium from Geothermal Brines. URL.
(11) Fastmarkets, 2020. Does DLE Matter?. URL.
(12) Alurralde, 2011. Recovery of Lithium Values from Sodium Saturated Brine. URL.
(13) Neo Lithium, 2021. Neo Lithium Produces 99.9% Battery Grade Lithium Carbonate. URL.
(14) Grant, A., 2020. Modeling Lithium Brine Re-Injection for a DLE Brine Operation at the Salar de Atacama. URL.