Stop Press

Five licence agreements signed as of April 2025

Two demonstration plants being built in 2025 – Texas USA, Jama Argentina

*Patagonia Lithium and American Salars test brines produce **99.8%** purity lithium carbonate using Ekosolve crystalline process!*

EkoSolve™

A DIRECT LITHIUM EXTRACTION METHOD USING SOLVENT EXTRACTION FOR LI-RICH BRINES

DLE SOLVENT EXCHANGE FOR THE FUTURE

Phil Thomas
Dr April Li
Professor Dr Kathryn Mumford

April 2025

EkoSolve Ltd
An Australian unlisted Public Company • ACN 657 738 120

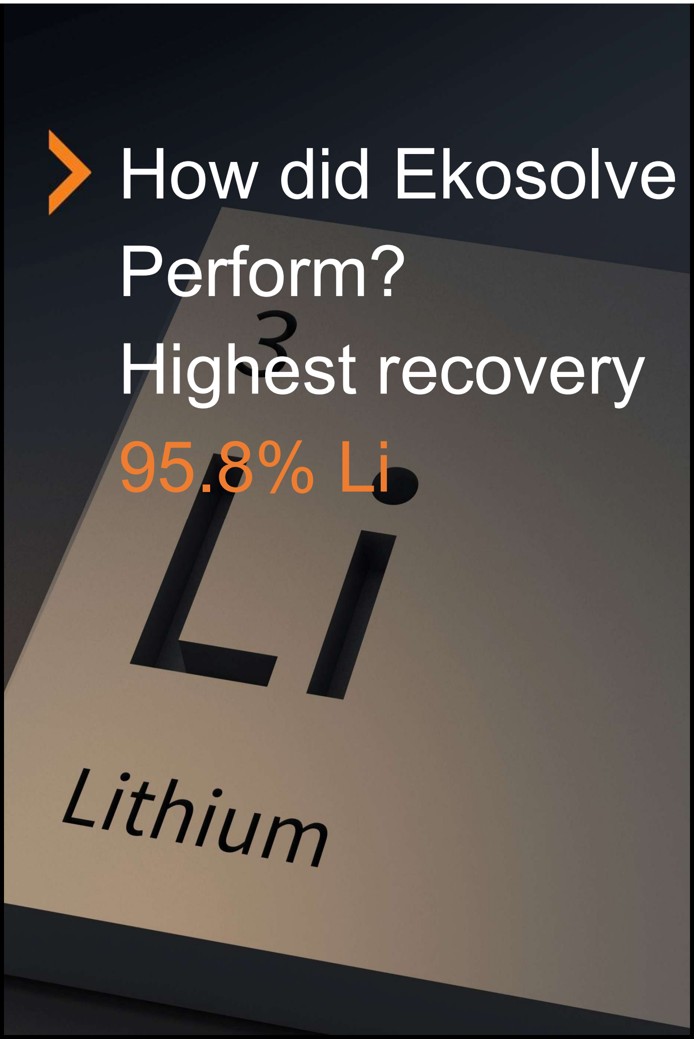
THE EKOSOLVE DLE ADVANTAGES

- High recovery of Li from brines as Lithium Chloride
- Produces Battery Grade Lithium Carbonate
- Circumvents problems of brine contaminants such as Mg, Ca and B that can interfere with the recovery and quality of Battery Grade Lithium Carbonate
- Eliminates the need for solar evaporation
- No requirement for large water volumes
- Single continuous process
- Low operating costs – 98.8% of solvent and reagents recovered
- Low capital costs
- Environmentally friendly process

OTHER DLE SYSTEMS ISSUES

sorbents, electrochemical, nano/membrane and ion exchange technologies

- Multiple phases of treatment – not continuous
- Large amounts of water consumption
- Membranes clogging up with waste ions
- Absorption plates denigrating quickly
- Ion exchange is selective to remove one ion type
- Electro-membrane still at concept stage and will probably need additional systems
- Most other DLE need high concentration of Lithium in brines
- Problems managing high Mg brines or brines with oil or highly acidic
- Extraction system can't be regenerated



- How did Ekosolve Perform?

Highest recovery

95.8% Li

Ekosolve Pilot Plant Results To-date

Salar/Location	Lithium content test concentration ppm	% extraction efficiency
Incahuasi	140.23	93.13
Pocitos A	85.96	94.92
Pocitos B	95.31	95.79
Rincon	195.0	92.00
Pozuelos	401.0	93.10
Formentera	266.76	92.06
Calgary Petrobrine	57.01	91.01
Stress test	37	91.8

THE LITHIUM MARKET IN 2023

Lithium is a critical commodity for the production of electric vehicles and renewables storage with demand expected to peak in 2028 onwards

The market is not in equilibrium as mining production cannot supply the future demand, evidenced by the recent lithium prices on acute shortages.

There are 53 projects in the post-preliminary economic assessment stage.

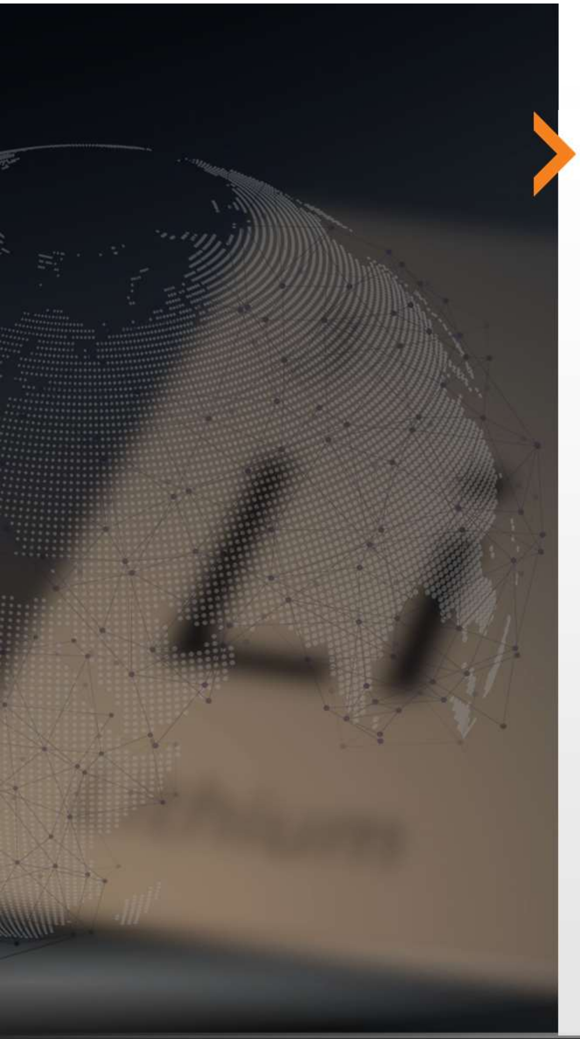
Of them, 11 were set to start production by 2024-25 but failed and 42 are projected for 2030.

Projects in the USA Texan oil belt and geothermal brines are developing with Li-rich brines. Argentina leads with 14 projects, all of which are Li-rich brines in the Lithium Triangle.

These projects have estimated capital costs ranging from $64 to $2,570 million, involving a total investment of $27 billion.

They are projected to increase supply with an additional 42 million tonnes of lithium carbonate.

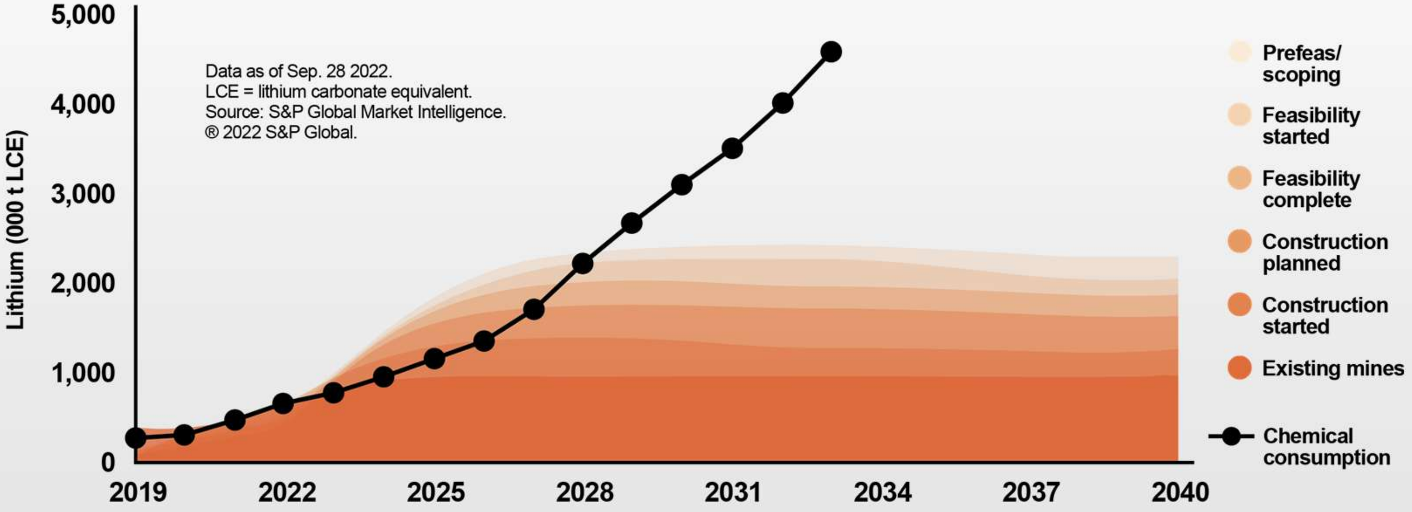
Ekosolve™ is the DLE of choice for five projects.



S&P Global Market Intelligence forecasts that even assuming the aggressive development of all these 53 projects, there will still be a demand gap of 605,000 tonnes of Li_2CO_3 by 2030.

To fill this gap and restore market equilibrium will require an additional investment of $38-40 billion.

PROJECT PIPELINE INSUFFICIENT TO MATCH LITHIUM DEMAND GROWTH



Data as of Sep. 28 2022.
LCE = lithium carbonate equivalent.
Source: S&P Global Market Intelligence.
® 2022 S&P Global.

The supply shortage is partly caused by the commercial methods used to extract the metal: **Solar evaporation and Selective ion-exchange resin.**

SOLAR EVAPORATION FOLLOWED BY ‘LIMING’ AND LI2CO3 PRECIPITATION

Used by:

- *Albermale in Silver Peak, USA,*
- *Albermale and SQM in Atacama, Chile, and*
- *Orocobre in Olaroz, Argentina.*

SOLAR EVAPORATION PRE-CONCENTRATION FOLLOWED BY LI SELECTIVE ION-EXCHANGE RESIN EXTRACTION

Used by:

- *Livent in Hombre Muerto, Argentina.*

More than half of Li production worldwide is made using these two methods.

Several other recovery systems have been proposed, although they have not been demonstrated commercially.

These commercial processes pose several problems

- Their construction is capital-intensive
- There is a long lead time from commissioning until the first production, determined by the time needed to solar evaporate the brines
- These processes negate the possibility of exploiting some brines:
  - the “liming” process precipitates Mg (and Ca) cations that co-precipitate with the Li_2CO_3. Brines with a Li to Mg ratio exceeding 1 to 10 are not economical and challenging because of the weight of the magnesium waste produced,
  - because of this, some Salares are not exploited, including Li-rich Salares in China, Argentina, and Uyuni in Bolivia,
- This explains the high capital intensity needed to develop a new mine.
- S&P Global Market Intelligence estimates that new projects will have an average capital intensity of $17,400 per tonne of Li_2CO_3 produced annually,
- These extraction methods have been criticised from an environmental point of view as unsustainable, particularly because of their **high water consumption**.

Phil Thomas at drill rig at Formentera Salar, Jama Argentina

ABOUT THE EKOSOLVE DLE SOLVENT EXTRACTION PROCESS

April 2025

In 2016, EkoSolve began investigating its **Solvent Extraction** process as an alternative to the conventional Li recovery methods.

What is *Solvent Extraction?*

Solvent Extraction, SX, also known as *liquid-liquid extraction*, is a method to separate compounds or metal complexes based on their relative solubilities in two different immiscible liquids, usually water (polar) and an organic solvent (non-polar).

The solvent that is enriched in the organic phase is the extract. The aqueous feed solution that is depleted in Li is the raffinate.

Its most significant advantage is the ability to selectively separate-out cations with very similar chemical behaviour and to obtain high-purity single metal streams from where the metal value can be 'stripped' from the 'loaded' organic phase, making it possible to precipitate the metal.

In this case, there is a net transfer of one or more species from one liquid into another liquid phase from the Li-rich brines to an organic solvent.

The transfer is driven by chemical potential, i.e. once the transfer is complete, the overall system of chemical components that make up the solutes and the solvents are in a more stable thermodynamical state; that is to say, the system has a lower free energy.

Lithium extraction

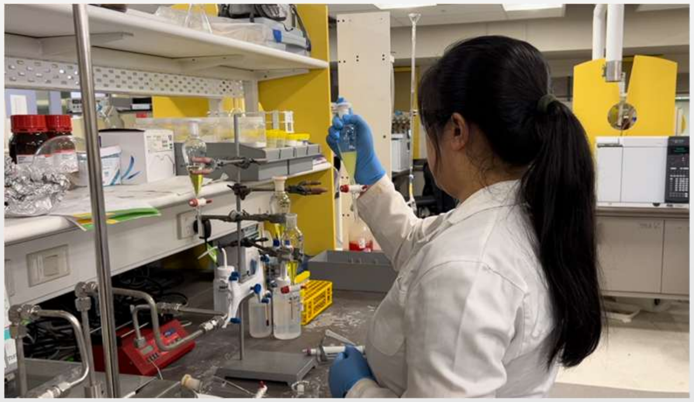
Lithium extraction has been studied extensively since the 1930s.

SX is a well-known, commonly used and well-tested commercial method for the recovery of metals.

SX is the preferred method to separate and purify metals such as Co, Cu, Nd, Ni, Pt and Pd, U, Po, Zr and Hf, Zn and Cd, and for the separation and purification of Rare Earth Elements.

In 2016, EKOSOLVE LTD undertook an exhaustive review of solvent extraction, leading to an exchange of information with Tsinghua University, China.

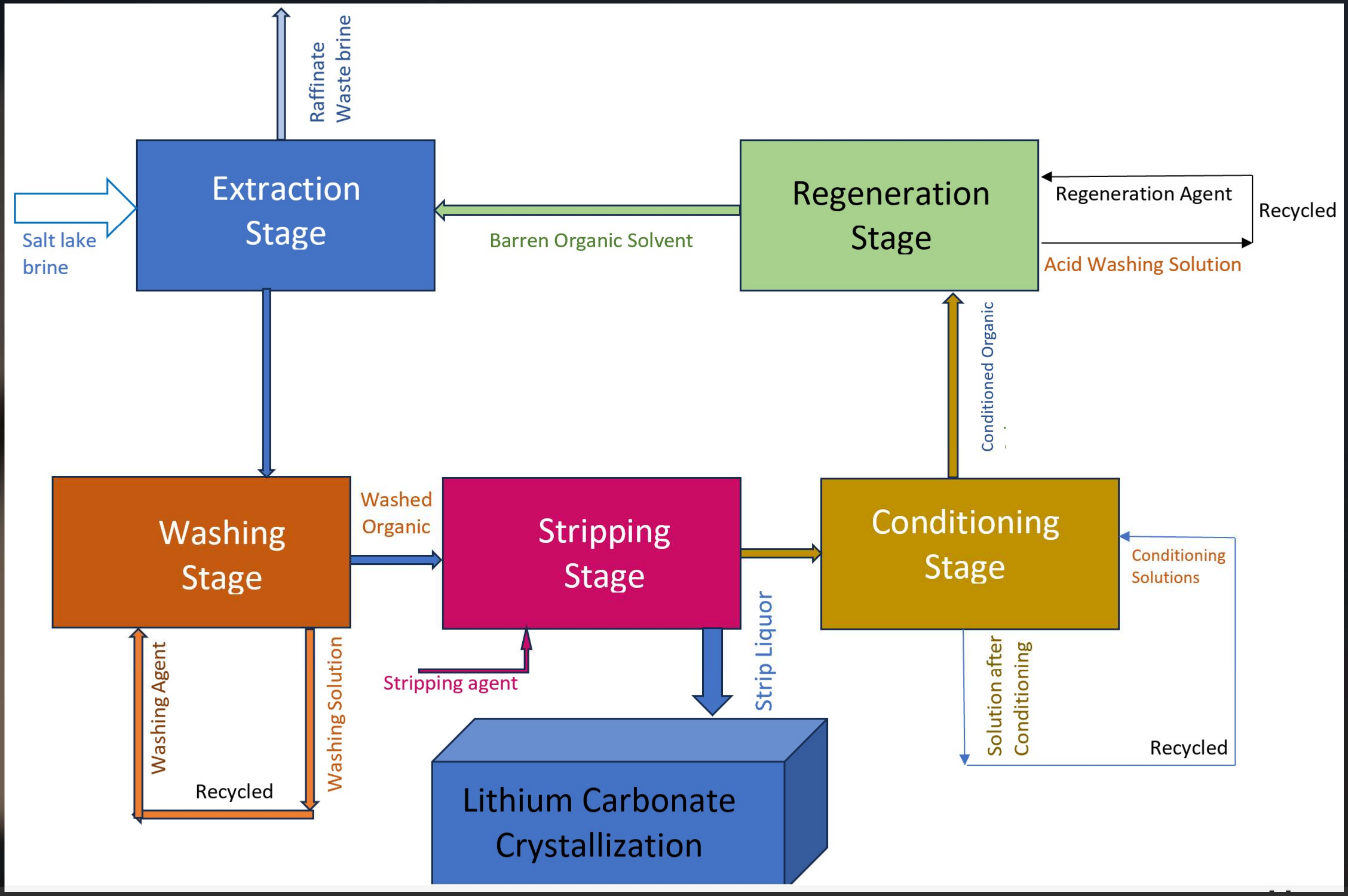
In 2017, the Department of Chemical Engineering of the University of Melbourne was engaged to carry-out extensive bench-scale and Pilot Plant tests aimed at ascertaining the feasibility of using SX to directly extract Li from Li-rich brines obtained from Argentinean Salares, leading to the development of EKOSOLVE.



What has Ekosolve's Research Achieved?

- More efficient use (reduction of solvent volume) of solvents in extraction process
- Capture and regeneration of more than 99% of solvents for re-use
- More efficient use of HCl acid in the stripping process
- Complete acid and solvent resistance of the extraction and stripping column lining
- Superior flow and fill rates into columns at each stage of the process making it semi-continuous
- Minimising the time for residence to extract 95% of the lithium in less than a minute
- Better production methodology of the li_2CO_3 production using a crystallizer rather than mixing tanks and membranes
- By-product generation of hydrogen and potassium chloride
- Water usage is reduced to a minimum (40,000 litres per one metric tonne of lithium carbonate) and only used to clean equipment and in the lithium carbonate phase with potassium carbonate to wash out the KCl
- Ekosolve is setting up an R & D Facility for further possible improvements in each phase of the process

THE EKOSOLVE PROCESS



Raffinate
Waste brine

Salt lake brine

Extraction Stage

Barren Organic Solvent

Regeneration Stage

Regeneration Agent

Recycled

Acid Washing Solution

Conditioned Organic

Washing Stage

Washed Organic

Stripping Stage

Conditioning Stage

Conditioning Solutions

Washing Agent

Washing Solution

Recycled

Stripping agent

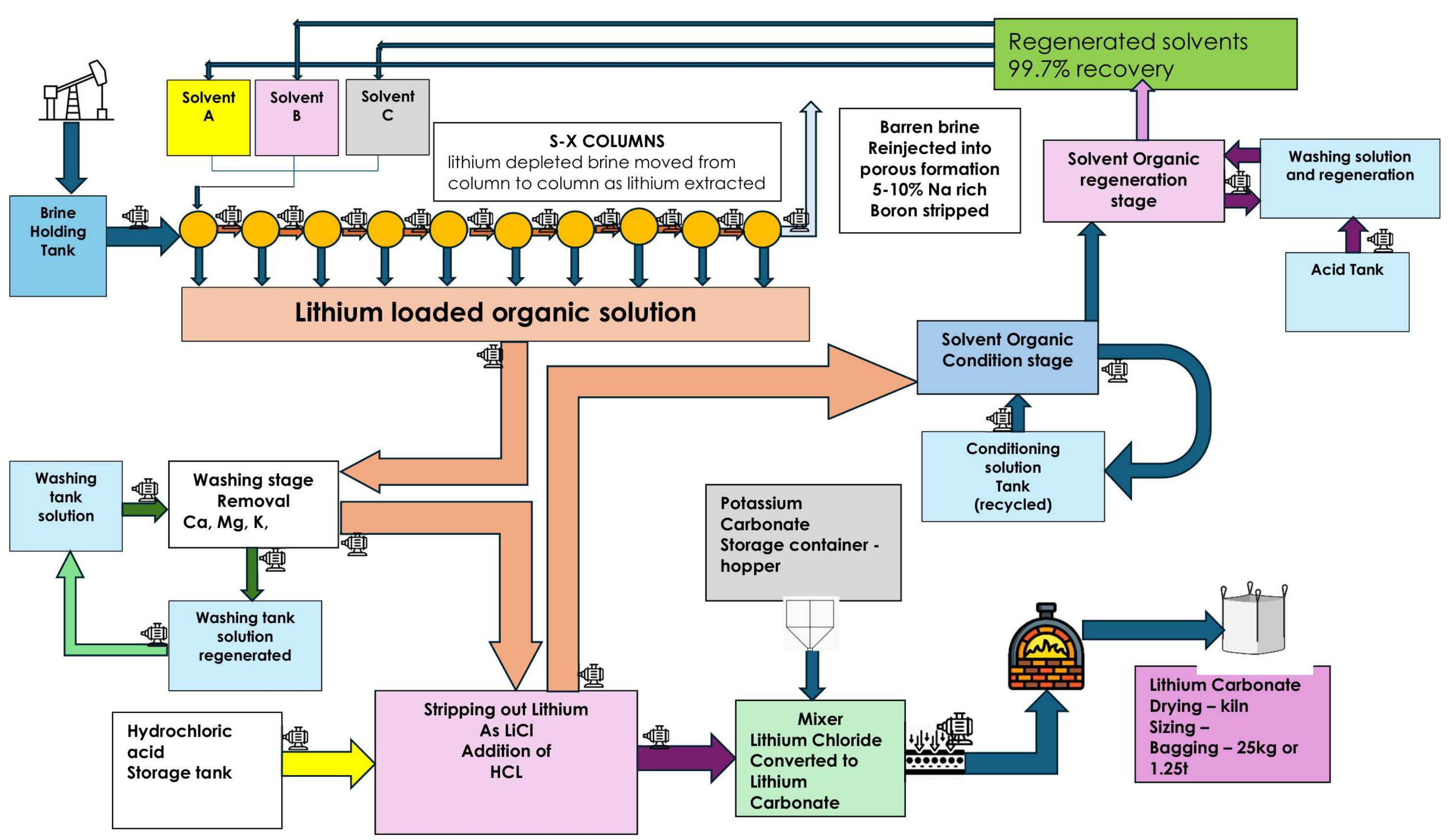
Strip Liquor

Solution after Conditioning

Recycled

Lithium Carbonate Crystallization

THE EKOSOLVE PROCESS



Regenerated solvents 99.7% recovery

Solvent A

Solvent B

Solvent C

S-X COLUMNS
lithium depleted brine moved from column to column as lithium extracted

Brine Holding Tank

Barren brine Reinjected into porous formation 5-10% Na rich Boron stripped

Solvent Organic regeneration stage

Washing solution and regeneration

Acid Tank

Lithium loaded organic solution

Solvent Organic Condition stage

Conditioning solution Tank (recycled)

Washing tank solution

Washing stage Removal Ca, Mg, K,

Washing tank solution regenerated

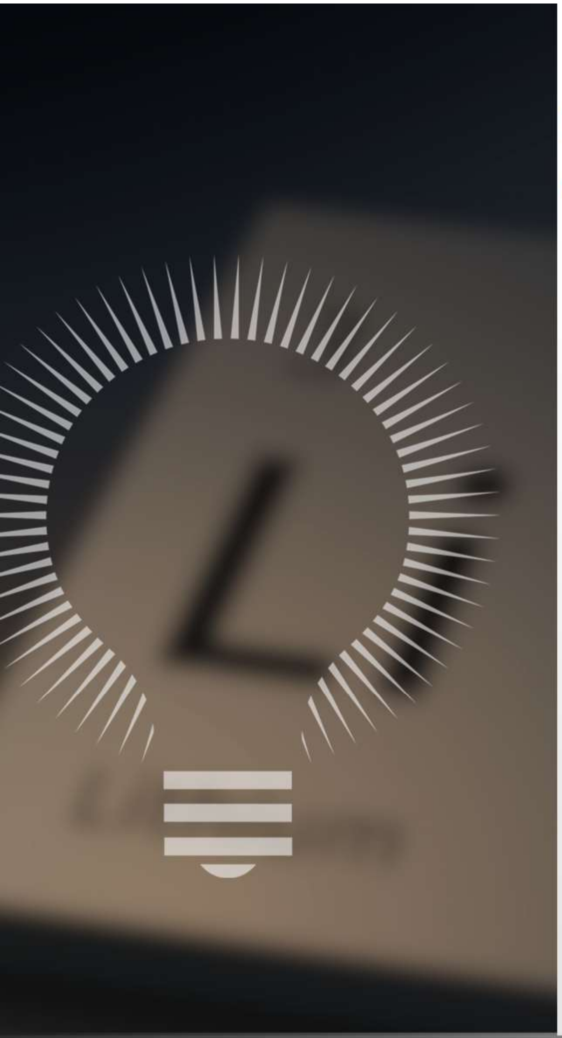
Potassium Carbonate Storage container - hopper

Hydrochloric acid Storage tank

Stripping out Lithium As LiCl Addition of HCL

Mixer Lithium Chloride Converted to Lithium Carbonate

Lithium Carbonate
Drying – kiln
Sizing –
Bagging – 25kg or 1.25t



EKOSOLVE consists of several stages

- **Preconditioning** of the Li-rich brines using a proprietary co-extractant, here symbolised as “**Cx**”, and hydrochloric acid;
- **Extraction** of the Li from the conditioned natural brines into an organic phase made of Tributyl Phosphate (**TBP**) as the extractant, dissolved in (**MIBK**) aided by Cx.

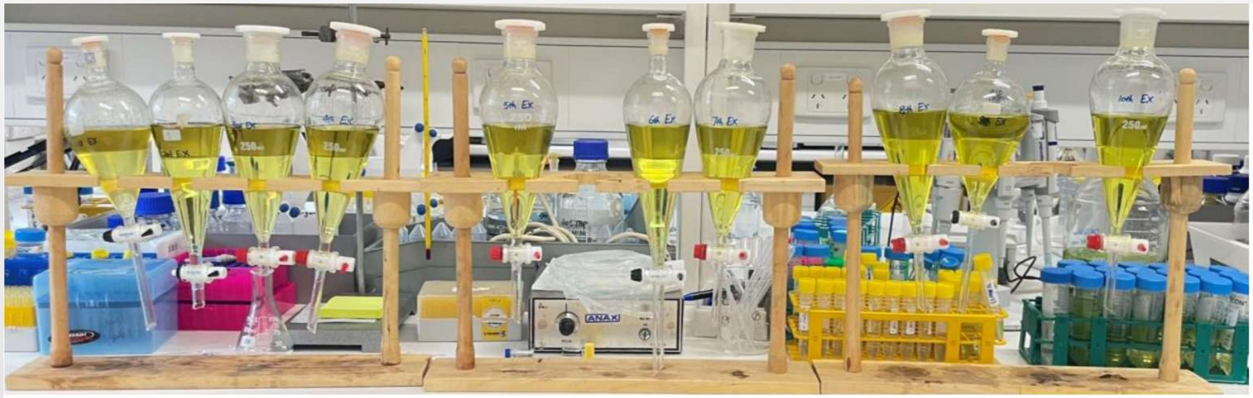
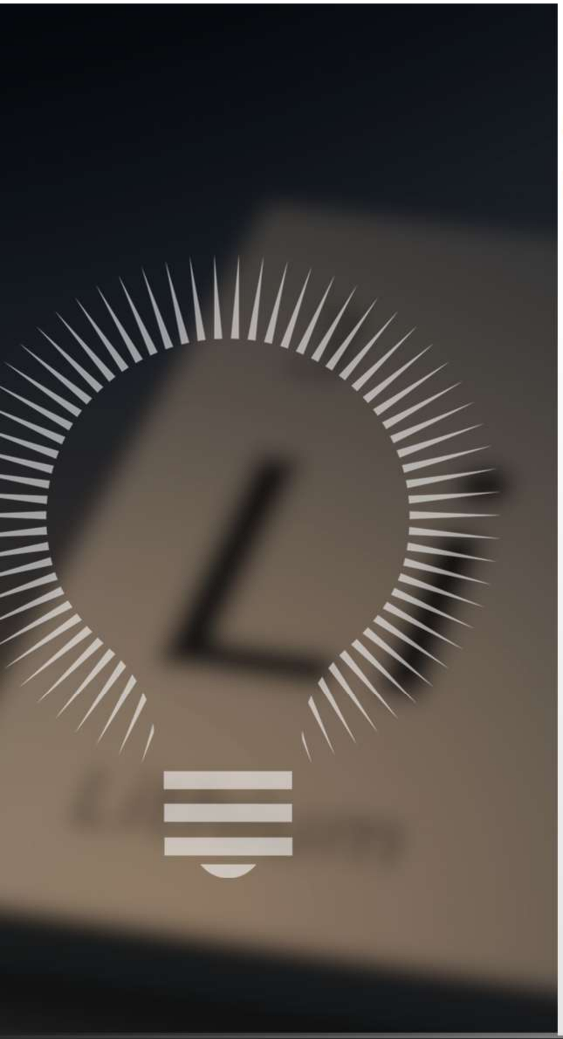


Figure 2 The experimental setup photo (in Separations Lab at the University of Melbourne)



- **Washing** to strip the Mg^{2+} from the loaded organic with a **minimum loss** of Li^{+} using LiCl and NaCl as the washing agents obtained from the stripping solution:

$$Li^{+}_{(aq)} + ½Mg(CxX)_{2}\bullet 2nTBP_{(org)}\ LiCxX\bullet nTBP_{(org)} + ½\ Mg^{2+}_{(aq)}$$

- **Stripping** of the organic phase with the help of hydrochloric acid:

$$LiCxCX\bullet nTBP_{(org)} + HCl_{(aq)}\ HCxCX\bullet nTBP_{(org)} + LiCl_{(aq)}$$

Higher HCl concentrations result in higher Li^{+} stripping efficiencies and lower Cx losses.

- **Regeneration** of the organic phase and the extractants.

THE EKOSOLVE CHEMICAL PROCESS IS:

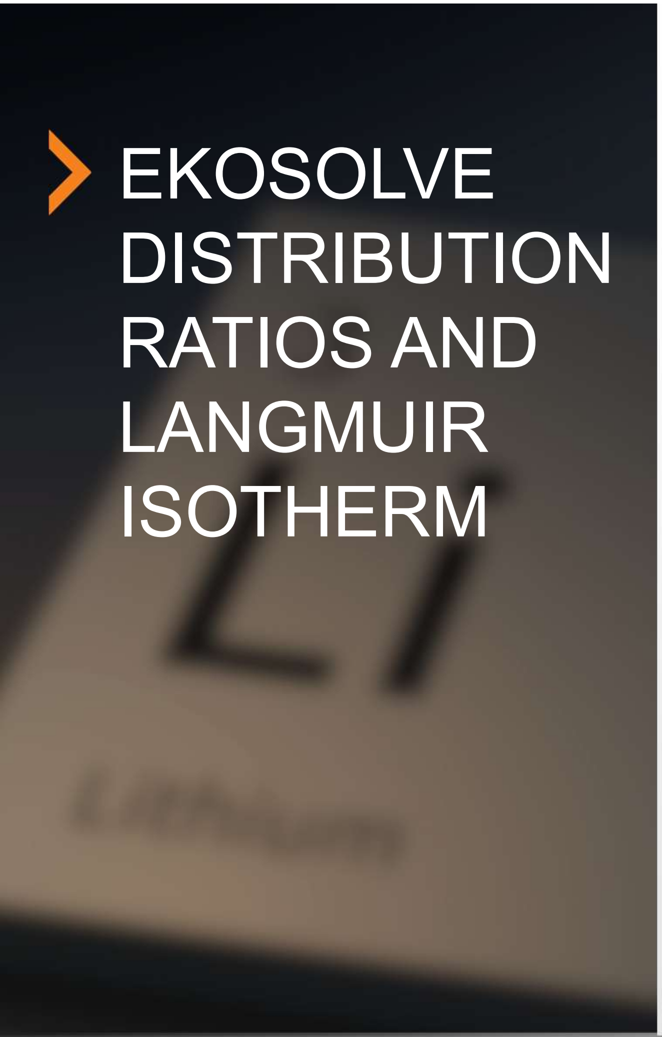
$$Cx_{(aq)} + Cl^-_{(aq)} \rightleftharpoons CxCl^-_{(aq)}$$

$$H^+CxCl^-_{(aq)} + nTBP_{(org)} \rightleftharpoons HCxCl^-\bullet nTBP_{(org)}$$

$$Li^+_{(aq)} + HCxCl^-\bullet nTBP_{(org)} \rightleftharpoons LiCxCl^-\bullet nTBP_{(org)} + H^+_{(aq)}$$

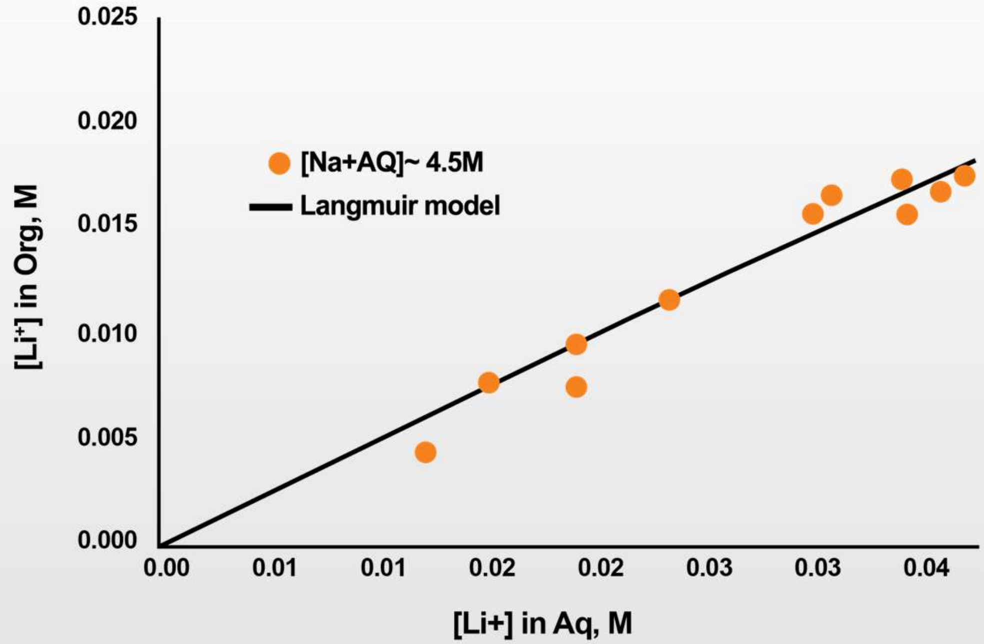
In this stage, some Mg^{2+} *is also extracted:*

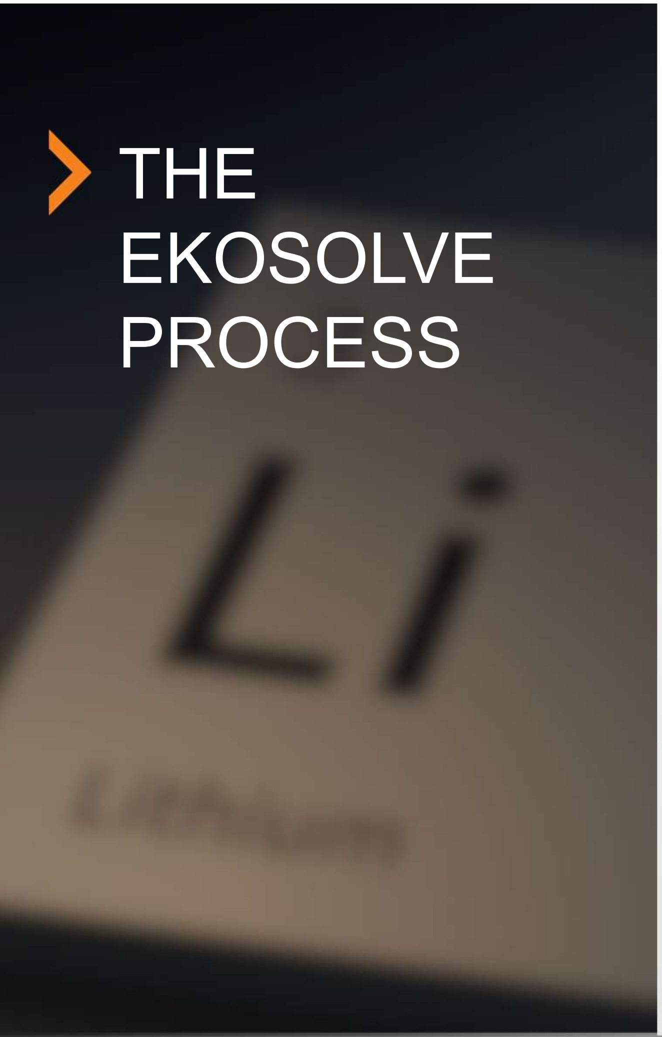
$$\tfrac{1}{2}\, Mg^{2+}_{(aq)} + NaCxCl\bullet nTBP_{(org)} \rightleftharpoons \tfrac{1}{2}Mg(CxCl)_2\bullet 2nTBP(org) + Na^+(aq)$$



EKOSOLVE DISTRIBUTION RATIOS AND LANGMUIR ISOTHERM

The EKOSOLVE process shows distribution ratios (K_d), the concentration of a solute in the organic phase divided by its concentration in the aqueous phase) of the order of 0.53. The distribution ratio, represented as a Langmuir isotherm, is shown in the figure.

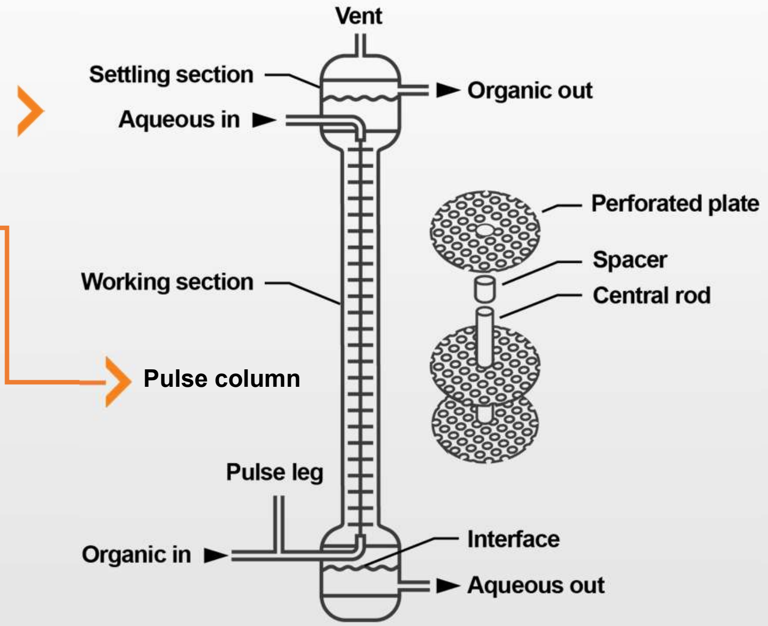


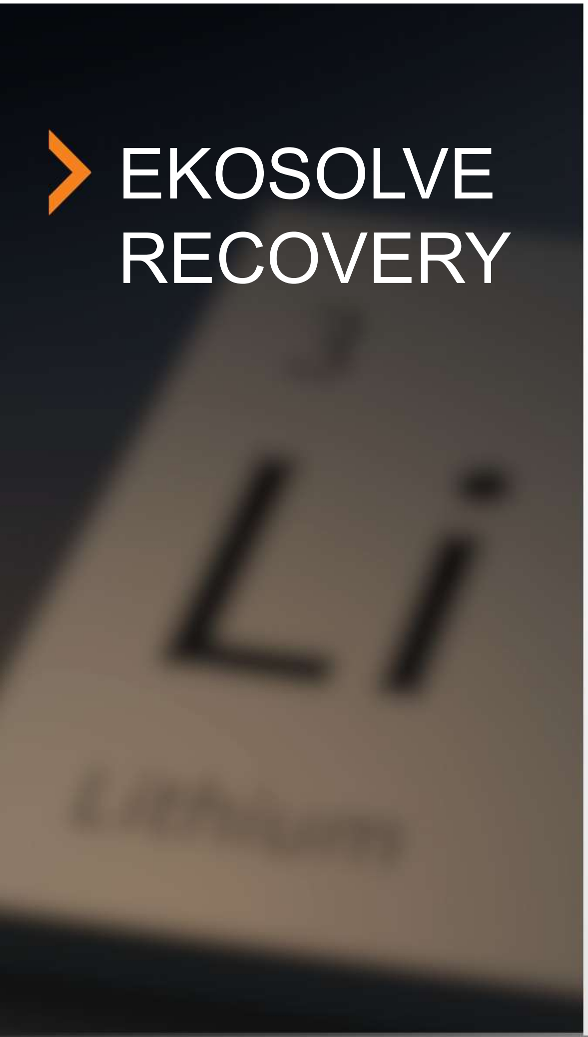


THE EKOSOLVE PROCESS

The EKOSOLVE process occurs in several sequential pulsed extraction columns, each consisting of a large diameter vertical column filled alternatively with disc and doughnut-shaped baffles, which facilitate contact between the immiscible liquids as they pass through the column.

- The aqueous phase enters through a disperser at the top of the column.
- The solvent phase enters through a similar device near the bottom.
- A decanter at each end of the column permits the liquids to coalesce and be poured out separately.
- When the solvent phase is continuous, the interface between the phases is in the lower decanter, and when the aqueous phase is continuous, it is in the upper decanter





EKOSOLVE RECOVERY

The testwork indicates that EKOSOLVE will recover Li economically from lithium-rich brines above 72 mg Li/L.

Our economic cut-off is 120mg Li/L

Once extracted, the exhausted raffinate from Stage 1 is fed to Stage 2, where the extraction is repeated.

The exhausted raffinate from Stage 2 is fed to Stage 3, and the extraction is repeated. As necessary. The overall recovery can be expressed as:

$$\rho_n = \sum_{i=1}^{n} \left([Li^+]_i \bullet \rho \right)$$

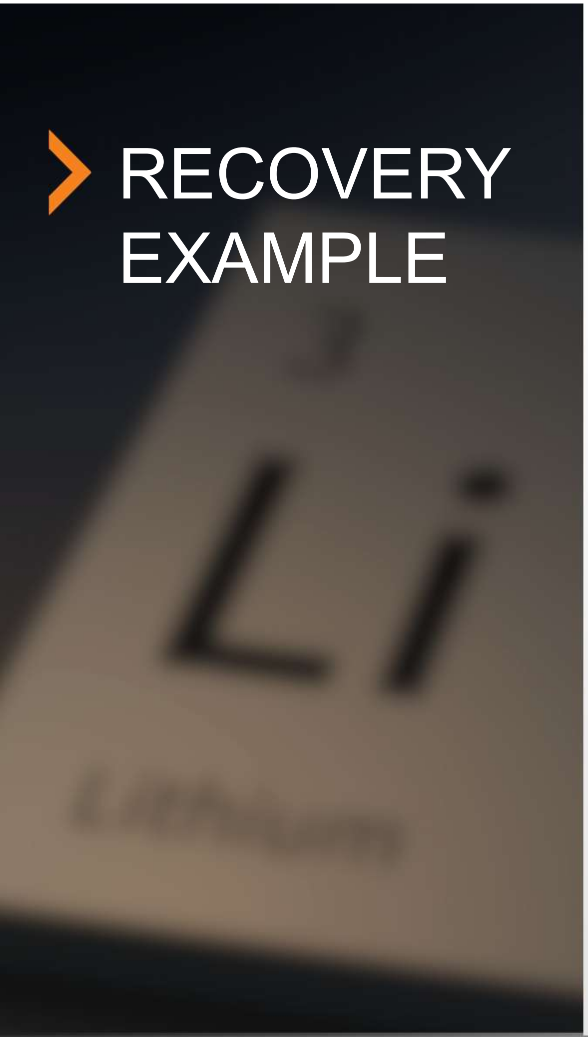
ρ is the recovery, expressed as a fraction of 1, such that $o \le \rho \le 1$;

n is the total number of stages;

i is the ordinal for each stage;

ρ_n is the total recovery after n-stages; and

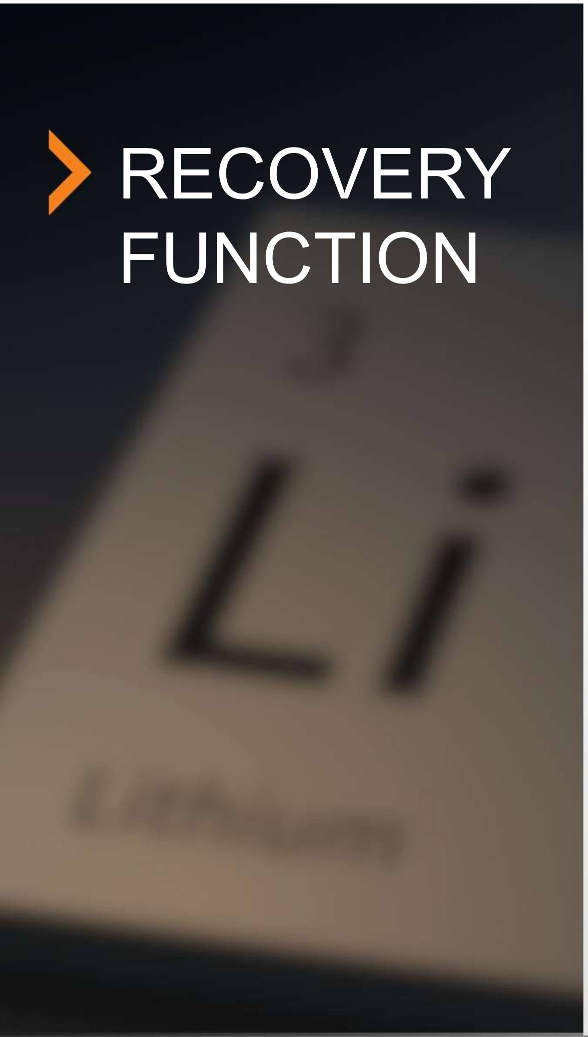
$[Li+]_i$ is the concentration of the metal in the feed of the i-stage.



RECOVERY EXAMPLE

An example of the process' recovery, based on **actual test measurements** performed on natural brines, is summarized below:

Recovered			
	Feed	**Raffinate**	**Recovered Li**
		Li$^+$ mg/L	
Stage 1	100.0	30.7	66.3
Stage 2	30.7	9.4	21.3
Stage 3	9.4	2.9	6.5
Total recovery			94.1

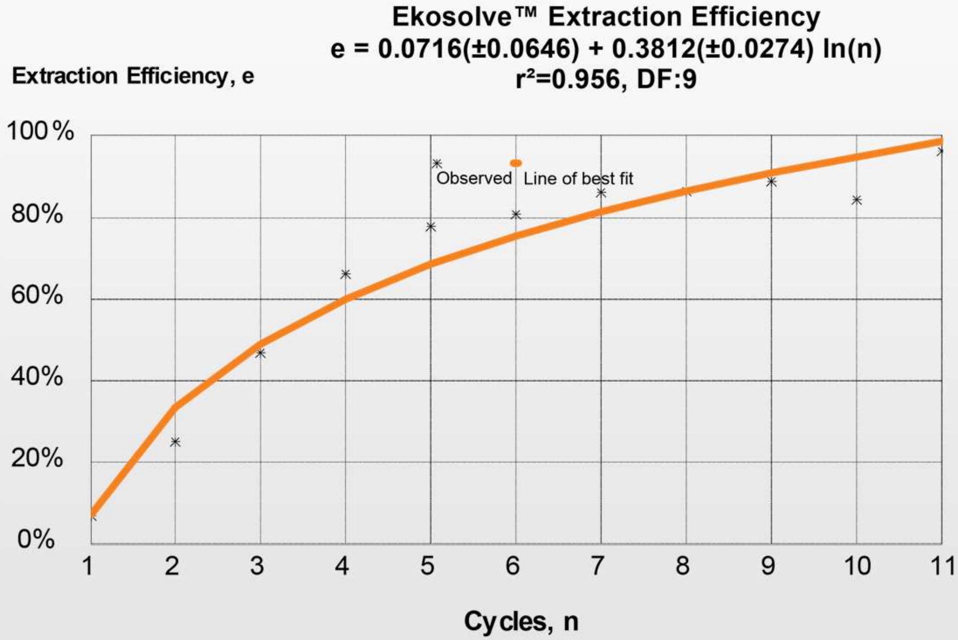


RECOVERY FUNCTION

As the number of stages increases, the lithium recovery approaches asymptotically to 100%.

However, after several stages, the recovery is marginally economic and does not compensate for the costs incurred.

The graph shows the course of this recovery function.



Ekosolve™ Extraction Efficiency

$e = 0.0716(\pm0.0646) + 0.3812(\pm0.0274)\ \ln(n)$

$r^2=0.956$, DF:9

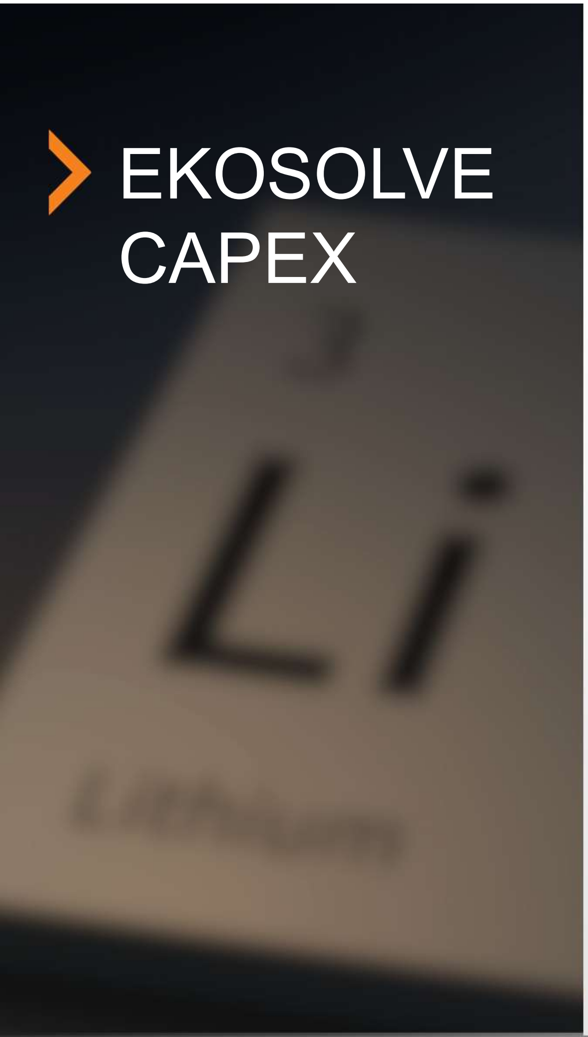
Lithium is recovered as Li_2CO_3 with a purity exceeding 99% which is battery grade

ESTIMATES OF CAPITAL AND OPERATING COSTS

Capital and Operating Costs have been appraised as an AACE's Class 2 Estimate, based on detailed unit costs with forced detailed take-off, an estimate with uncertainty in the range from -15% to +37%

The estimates are based on February 2023 prices for a plant capable of producing 20,000 tonnes per year of Battery Grade Lithium Carbonate.

The estimates do not include financial costs, fiscal taxes and royalties and do not account for inflation since 1 Jul 2023.



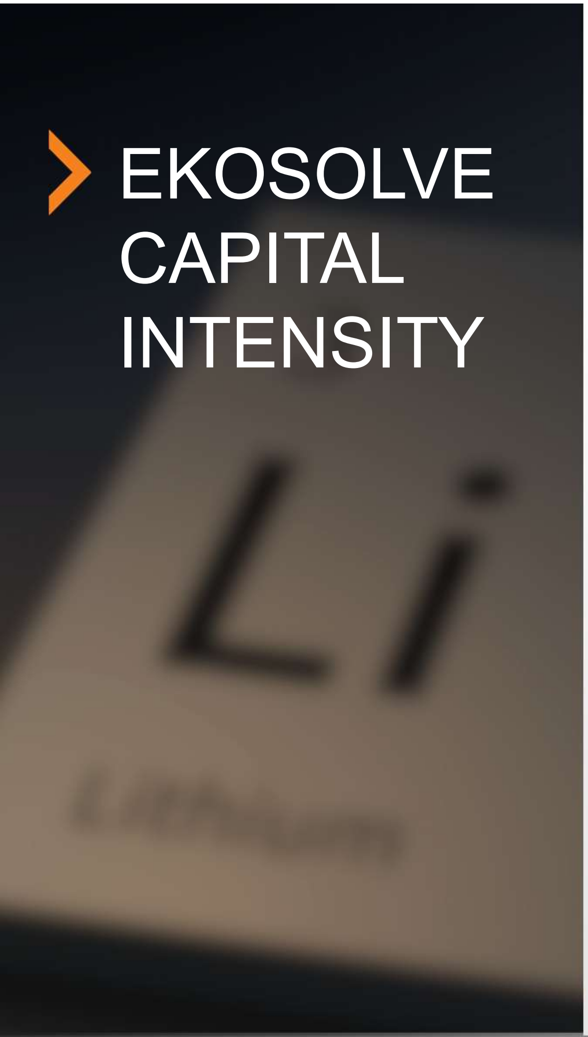
EKOSOLVE CAPEX

The capital investment required for a plant capable of producing 20,000 Li_2CO_3 per year is expected to be US$197M, ranging from a low of US$171M to a maximum of US$270 million.

This uncertainty arises from the conditions of each project, such as location, ease of access, power availability, reagents' import duties, disposal of waste brines etc.

The figure below shows estimates for several plant capacities.

EkoSolve™ Capital Costs



EKOSOLVE CAPITAL INTENSITY

Capital Costs can be amortised over the annual production to estimate the unit costs per tonne of Li_2CO_3 produced, a Capital Intensity that allows for a comparison of relative capital requirements between EKOSOLVE™ and other brine projects.

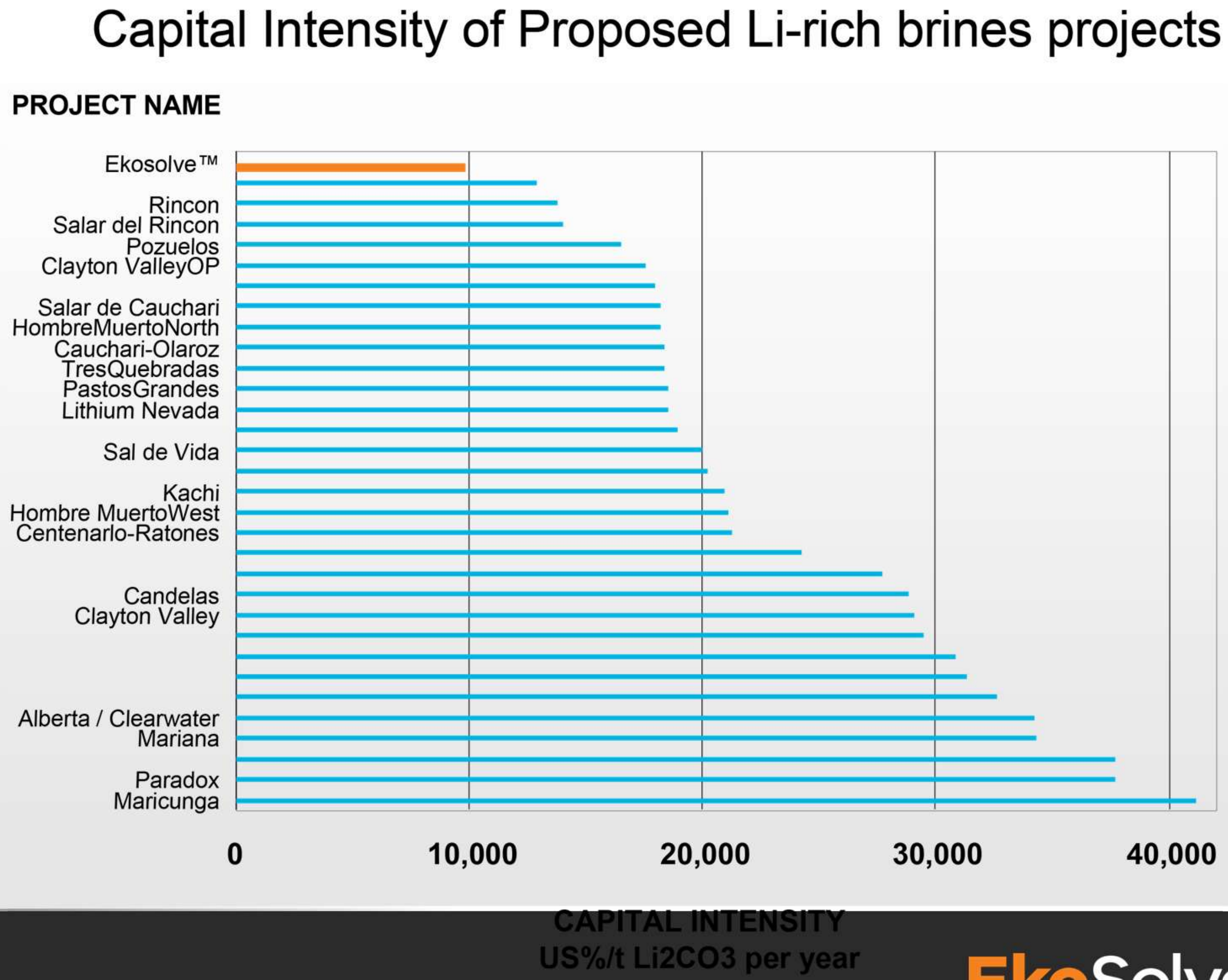
EkoSolve™ Capital Intensity, US$ per tonne of Li_2CO_3 produced annually

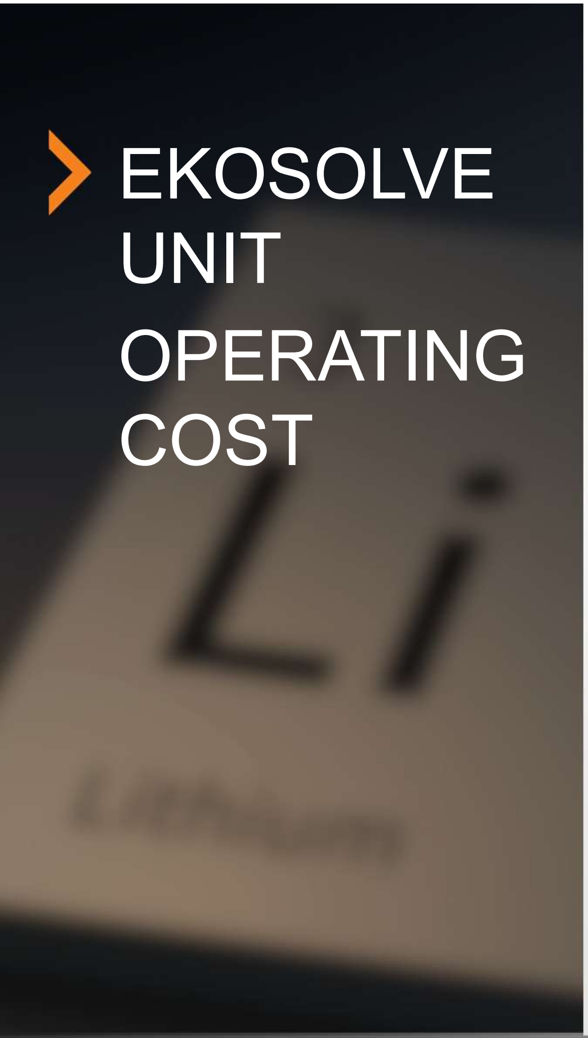
	Low	Expected	High
Pulsating extraction column	2,985	3,431	4,701
Initial reagent load	2,902	3,336	4,570
Plant civil installations	746	858	1,175
Generators & power works	580	667	914
Mobile plant	332	381	522
Caustic electrolytic plant	249	286	392
ECPM	779	896	1,227
Recovered	**8,573**	**9,855**	**13,501**

EKOSOLVE CAPITAL INTENSITY

With a Capital Intensity of US$ 9,855 per tonne of Li_2CO_3 produced annually, EKOSOLVE compares well with the capital intensity of other proposed brine projects.

Even at its maximum estimated Capital Intensity of US$13,500, EKOSOLVE is still positioned as one of the lowest investments required to develop a Li-rich brine project.





EKOSOLVE UNIT OPERATING COST

The EkoSolve operating costs can be estimated at US$2,710 per ton of battery-grade of Lithium Carbonate produced.

The opex has been averaged over ten years; that is to say, it includes commissioning expenses. TPK and MIBK and HCl are the major costs.

This Opex does not include the amortisation of the plant capital costs or its maintenance.

Operating costs amortized over 10 years of production, US$/t

	Low	Estimated	High
Reagents	1750	2060	2820
Fuels and Energy	460	540	740
Labour	90	110	150
Operating Costs total	**2300**	**2710**	**3710**

THE EKOSOLVE ADVANTAGES

- High recovery of Li from brines as Lithium Chloride
- Produces Battery Grade Lithium Carbonate
- Circumvents problems of brine contaminants such as Mg, Ca and B that can interfere with the recovery and quality of Battery Grade Lithium Carbonate
- Eliminates the need for solar evaporation
- No requirement for large water volumes
- Single continuous process
- Low operating costs – 98.8% of solvent and reagents recovered
- Low capital costs
- Environmentally friendly process

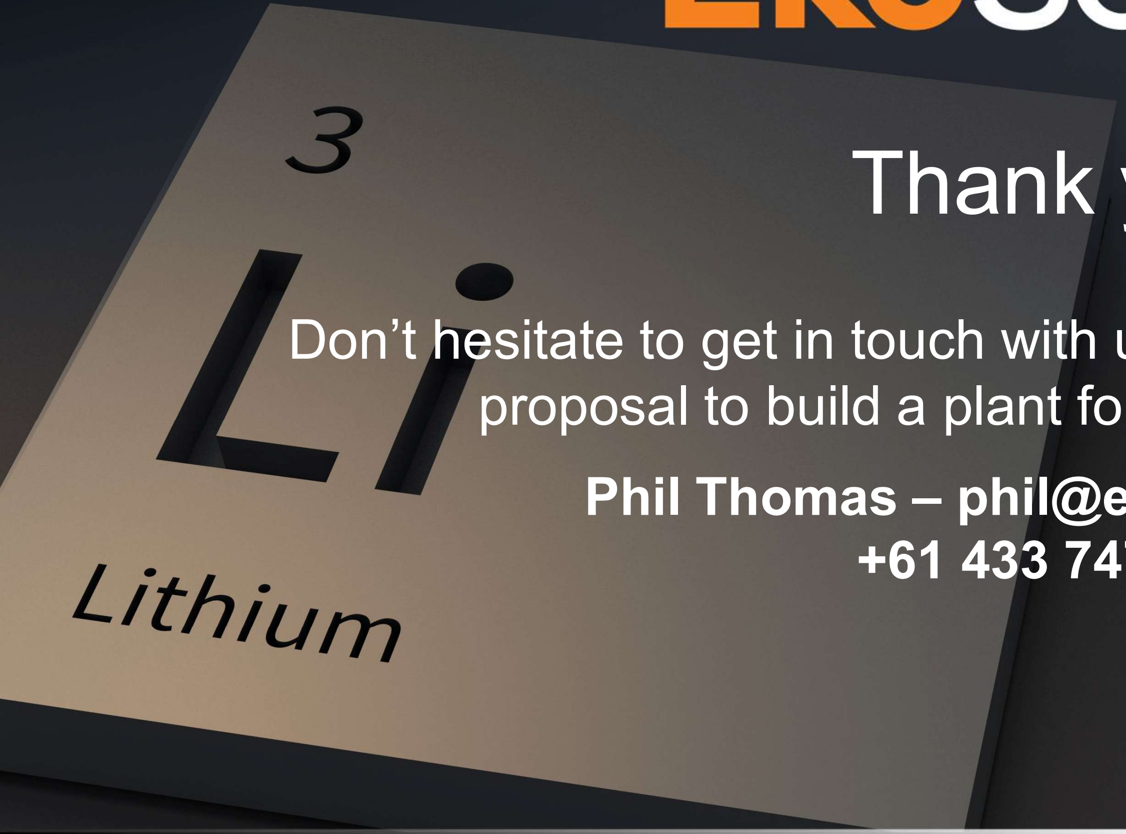
TYPICAL SOLVENT EXTRACTION PLANT

EKOSOLVE TECHNOLGY REVIEW

Various DLE technologies and the risk matrix.

	Capital	Operation Complexity	Lithium Recovery	Development time	Operating Expenditure	Environment	Reagent Supply	Reagent Recovery	Safety	University Collaboration
EKOSOLVE®	🟩	🟩	🟩	🟨	🟩	🟩	🟨	🟩	🟩	🟩
A - Solvent/Ion Exchange	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
B - Adsorption	🟨	🟥	🟩	🟨	🟥	🟥	🟨	🟥	🟨	🟨
C- Adsorption Combination	🟥	🟥	🟨	🟨	🟨	🟨	🟨	🟥	🟨	🟨
D - Ion Exchange/Rev Osmosis	🟥	🟨	🟨	🟨	🟨	🟨	🟥	🟩	🟥	🟨
E - Ion Exchange	🟨	🟩	🟨	🟨	🟩	🟨	🟨	🟩	🟨	🟥
F - Conventional	🟥	🟩	🟥	🟥	🟩	🟥	🟩	🟥	🟨	🟨

🟩 Low Risk 🟨 Medium Risk 🟥 High Risk



EkoSolve™

Thank you

Don’t hesitate to get in touch with us for further information or a proposal to build a plant for your lithium project.

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www.Ekosolve.com.au