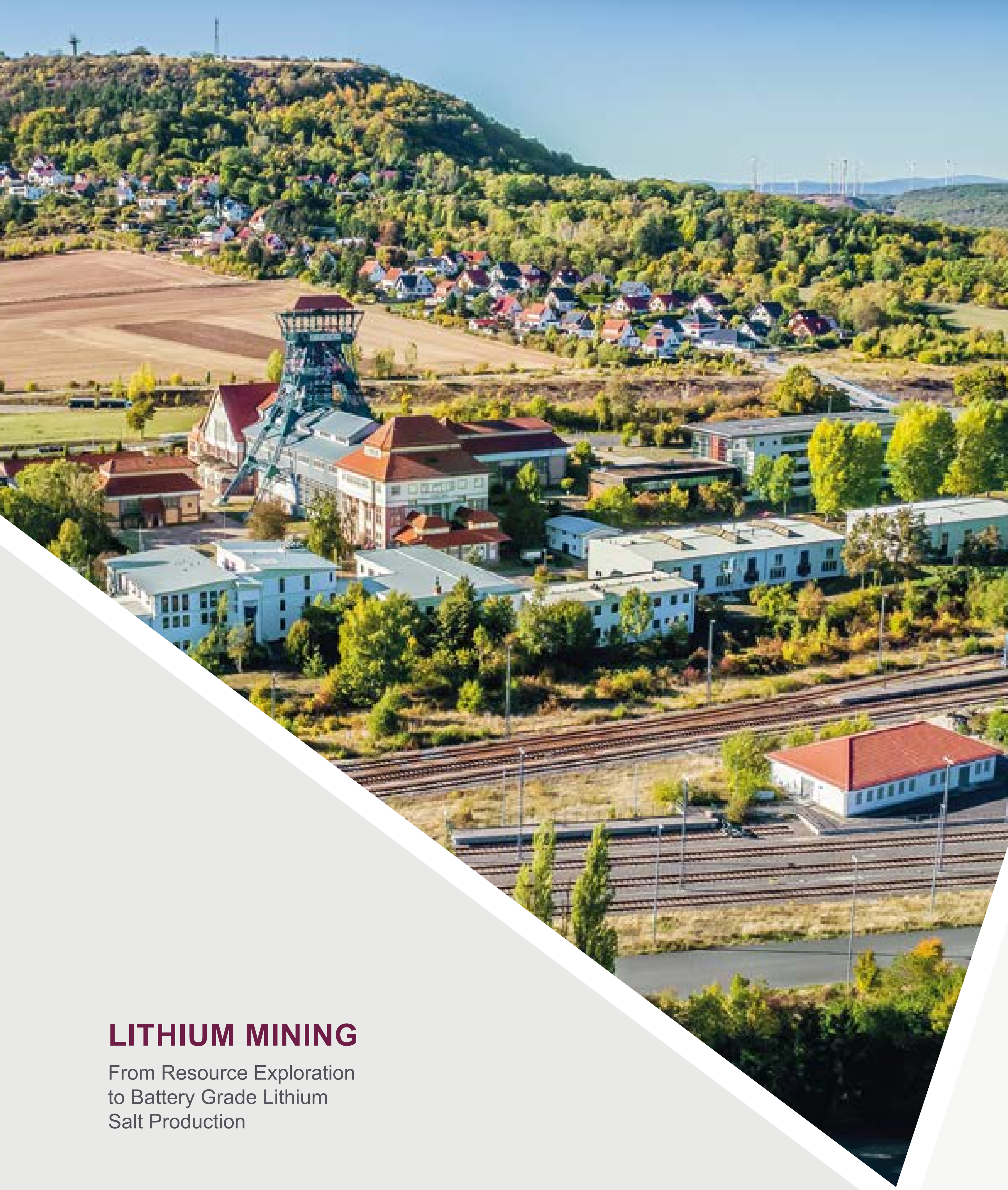


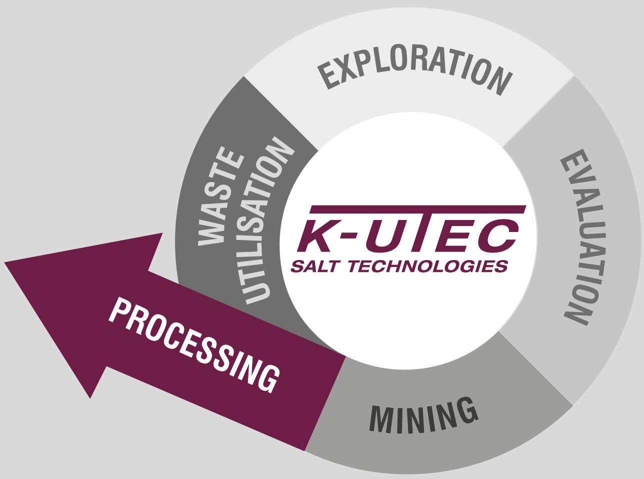
# LITHIUM MINING

From Resource Exploration
to Battery Grade Lithium
Salt Production

K-UTEC
SALT TECHNOLOGIES

# K-UTEC AG SALT TECHNOLOGIES

## The One-stop Service Provider for Mineral and Salt Mining and Processing




### More than 70 years of experience in Mineral and Salt Mining and Processing ...

**... stand for continuity, competence, and highest quality standards.**

K-UTEC is an internationally recognised professional service provider for planning, design, engineering, and construction management of mineral and salt mining and processing projects focusing on lithium and potassium salts. For more than 70 years, we have been helping our customers to realise even the most complex projects and ensure their economic success. Our experts support the development of mining projects at every stage, from prospection, exploration, basic and detailed engineering, financing support, and supply of key equipment to commissioning. The range of services also includes complementary services such as monitoring the geomechanical stability of mines or other sensitive infrastructure, environmental monitoring or recycling, and final disposal of industrial and mining waste.
Our thinking without limits, decades of experience, a fully equipped demonstration plant for solid and liquid raw materials, and a strong focus on a “customer is king” philosophy give us a decisive competitive advantage.

# Exploration of Lithium Resources

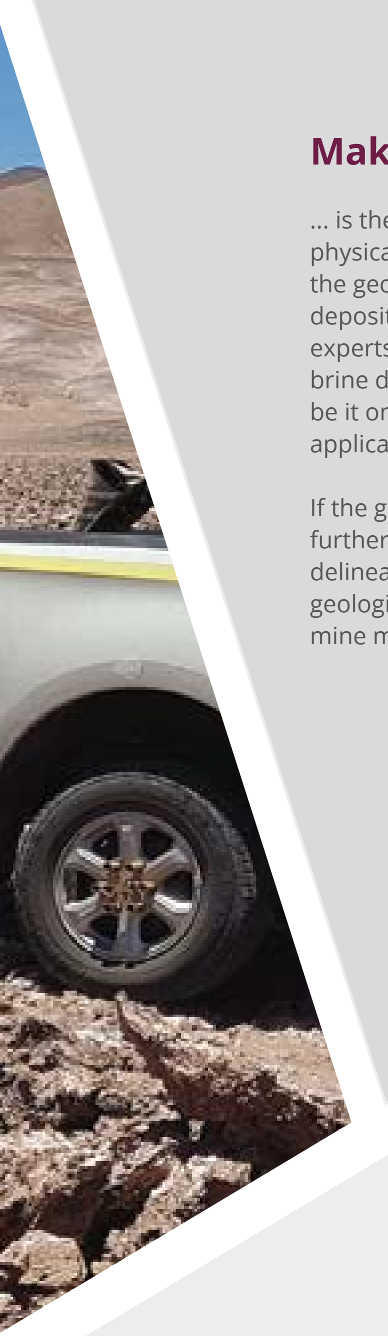
## Lithium Resources

Although lithium is an abundant element, few mineable sites have sufficient concentrations and acceptable general mining conditions. With about 60% of the world's identified reserves, salt deposits containing lithium brines are the primary source of lithium. About 78% of these lithium brine deposits are located in the subsurface of salars or salt flats (dried-up salt lakes), with a lithium content of 0.2 to 6 g/l. Other brine deposits are: Concentrates from salt lakes, mineralised waters of geothermal origin or from petroleum reservoirs, as well as residues from sodium chloride extraction from seawater or waste water from seawater desalination plants. Other significant lithium deposits are found in lithium-bearing ores and lithium clays. In ores, the highest lithium concentrations are found in granitic pegmatites such as spodumene and petalite, with typical concentrations in the range of 1-2% $Li_2O$. These generally low concentrations require a concentration step prior to metallurgical processing of the ore and lithium leaching can be carried out. Lithium is found in more than 145 different minerals, with spodumene being the most abundant lithium ore. Lithium is generally found in lower concentrations in clay minerals, primarily in smectites, mica, and fibrous clays. Lithium occurs most frequently in clay minerals by isomorphous substitution, but may also be present as an impurity, as an inclusion, in lattice cavities, or adsorbed on the surface.

**Table 1: Selected commercially important lithium ores**

| Lithium Ores | Formula | Li-Weight % | Group | Geological Settings |
|---|---|---|---|---|
| **Spodumene** | $LiAl(SiO_3)_2$ | 3.73 | Pyroxene group Clinopyroxene subgroup | In lithium rich pegmatites |
| **Lepidolite** | $K(Li,Al)_3(Al,Si,Rb)_4O_{10}(F,OH)_2$ | 3.58 | Trioctahedral mica group | May be found in aplites associated with granite pegmatite. rarely found in hydrothermal veins |
| **Petalite** | $LiAl(Si_2O_5)_2$ | 2.09 | feldspathoid group | In lithium rich pegmatites |
| **Amblygonite** | $(Li,Na)AlPO_4(F,OH)$ | 3.44 | Amblygonite group | Zoned granite pegmatites, high- temperature tin veins, greisens |
| **Eucryptite** | $(LiAlSiO_4)$ | 5.51 | Phenakite group | In lithium-rich pegmatites, often as graphic intergrowths with albite derived fromalteration of spodumene |
| **Virgilite** | $LiAlSi_2O_6$ | 4.74 | Tektosilicate group | found in volcanic glass (e.g. Macusani deposit in Puno, Peru) |
| **Montebrasite** | $LiAl(PO_4)(OH)$ | 0.54 - 3.52 | Amblygonite group | A late primary mineral in zoned,complex granitic pegmatites. |
| **Jadarite** | $LiNaSiB_3O_7(OH)$ | 3.16 | Chlorite group | "Unique of Jadar Basin in Serbia; composed of a sequence of oil-shales, dolomicrites and pyroclastic deposits of Neogene" |
| **Zinnwaldite** | $KLiFeAl_2Si_3O_{10}(F,OH)_2$ | 1.59 | Mica group | Pneumatolytic mineral occurring in cassiterite and topaz-bearing pegmatites. |
| **Hectorite** | $Na_{0,3}(Mg,Li)_3Si_4O_{10}(OH)_2$ | ~1.93 | Smectite group mineral | Clay mineral from altered volcanic tuff ash with a high silica content related to hot spring activity |
| **Bikitaite** | $LiAlSi_2O_6H_2O$ | 3.40 | cyclosilicate tourmaline group | Occurs as a late-formed mineral in fractures in lithium-rich pegmatites |

# Geological and geophysical exploration and modeling of solid and brine lithium deposits, including resource and reserve calculation



## Making the invisible visible ...

... is the ambitious goal of our experts in geophysical exploration. The use of non-intrusive geophysical surveys is the most cost-effective and appropriate tool to obtain basic information about the geological, hydrogeological, and petrophysical properties of the subsurface of a salt or brine deposit. With seismic, geoelectric or radar-based methods applied by internationally recognised experts (qualified persons), we can collect the necessary data for the initial exploration of salt and brine deposits. With geophysical measurement methods, we make visible what was invisible before, be it on the surface, in the shallow subsurface, in boreholes, or through the complementary application of validated mathematical models to simulate stratigraphic horizons.

If the geophysical surveys prove sufficiently interesting, subsequent drilling and further investigation will be required to confirm the accuracy of the results, delineate the deposit more precisely, and obtain geochemical, hydrogeological, and other data necessary to develop a conceptual mine model and determine project feasibility.

## Typical Geological and Geophysical Services provided in the Exploration Phase from Scoping to Bankable Feasibility Studies

**1. Preparation Phase**
- Comprehensive research and acquisition of relevant and available data to evaluate the geographical, geomorphological, geological, hydrogeological, hydrometrical and economic conditions of the exploration area
- Development of an extensive exploration concept and program

**2. Geophysical and geological Services**
Fieldwork (implementation of the exploration program)

**3. Geological modeling**
- Geological and Hydrogeological modeling of the tenement areas
- Block models and flow models of the exploration areas

**4. Resource and Reserve Calculation**
- QP (Qualified Person – European Geologists)/QC (Quality Control)
- Calculation of the Resources and Reserves according to international standards

**5. Reporting**
- Preparation of exploration reports with a summary and interpretation of gained information on deposit delineation and resource estimation
- Development of a targeted concept and program for further site investigations, including drilling and hydrogeological investigations
- International reporting standards (including e.g. NI 43-101 and JORC Code)

## Applied Technology

- Geoelectric sounding, mapping, 2D/3D tomography
- Electromagnetic exploration (e.g. TEM, GPR)
- Magnetic and VLF measurements
- Seismic and electromagnetic tomography
- Seismic reflection and refraction, surface wave exploration (e.g. MASW), hybrid seismics
- H/V seismic exploration
- Borehole seismic exploration, VSP measurements
- Sonar investigation
- Surface and borehole radar
- Measurements of borehole deviation
- Drone survey (Photogrammetry, LiDAR, etc.)

## Applications

- Deposit exploration, modeling and evaluation
- Hydrogeological and geohydraulic investigation and modeling
- Investigation of layer boundaries and geological structures
- Cavity investigation
- Petrophysical parameter exploration
- Infrastructure surveillance
- Preliminary route survey
- Quality control


# Certification and qualifications of Geology and Geophysics Departments

K-UTEC is a registered quality geophysics company, according to the Professional Association of German Geoscientists (BDG).
A team of qualified, geologists experienced engineers guarantees the efficient execution of projects, from conceptual design to planning and implementation.
The Geophysics department is certified according to EN ISO 9001:2008. We count on two specialists certified as Qualified Persons, which can prepare, evaluate, and sign internationally accepted “bankable” reports according to e.g. NI43-101and JORC. Both specialists are accredited as European Geologist.

We are officially registered pursuant to Art. 26 Federal Immission Control Act (BImSchG) for the performance of besser seismic vibration Measurements accredited for vibration detection in the context of emission protection **(Reg.: D-PL-14237-01- 00).**

# Brine and Mineral characterisation in our EN ISO 17025 accredited laboratory

DAkkS
Accreditation

## When measurement technology alone is not sufficient ...

... then experience can help. A sample's actual mineralogical structure can often only be identified with X-ray diffraction phase analysis supported by microscopy. Especially for samples with low concentrations, a high degree of experience and expertise is just as important as modern analytical technologies. At K-UTEC, we have both.

# RANGE OF ANALYTICAL SERVICES

## Salt analysis and mineralogy

**Salt analysis**

- Chemical composition of all types of salts and minerals.
- Analysis of salts of natural and industrial origin.
- Analysis and quality control of process waters and intermediate and final products.
- Analysis of concentrated salt solutions and solid samples.
- Analysis of mine waters and low salinity waters.
- Analysis of drilling cores.

**Mineral analysis**

- Mineralogical structure of all kinds of salts and minerals of natural and industrial origin and industrial processes.
- Mineralogical analysis of products from the processing of saline salts.
- Mineralogical analysis of industrial crystalline waste (e.g. filter dust).
- Microscopic analysis of salts and minerals, including characterisation of the degree of intergrowth.

## Environmental analysis

**Analysis of complex matrices and mixtures of substances**

- Chemical analysis of main organic and inorganic components.
- Routine trace analysis for inorganic and organic parameters.
- Chemical analysis of wastewaters and industrial waste Chemical analysis of gases and vapors from mines and industrial processes.

## R&D activities

**Specialist areas and expertise**

- Chemical and mineralogical analysis of brines, salts, and minerals.
- Monitoring of saline stockpile wastewaters Mineralogical and chemical analysis of drilling cores.
- Chemical and mineralogical analysis for process monitoring and recommendations for action.
- Interpretation of measurement results and recommendations for action.
- Development and validation of measurement methods.
- Calculation of ionic balances and mineral compositions.

## Official (DAKKS) accreditations

The Chemical and Physical Engineering department is a test laboratory **accredited to EN ISO 17025** by the German Accreditation Body DAKKS. A dedicated team of chemists, analysts, and mineralogists guarantees a high level of reliability in determining, evaluating, and interpreting analytical data.

We are a publicly recognised wastewater testing laboratory pursuant to Art. 8 Regulation of the Free State of Thuringia on wastewater self-monitoring (ThürAbwEKVO).

# Lithium Process Technology

# Lithium separation in Brines and Minerals

## Evaporation - Crystallization Process for brines

The traditional method to recover lithium from natural brines containing a variety of dissolved minerals is a fractional crystallisation in evaporation ponds using solar energy.

Natural brines bear dissolved chlorides and sulfates of sodium, potassium, magnesium or calcium, borates, and lithium as the main components in most relevant occurrences. The solar-driven fractional evaporation crystallisation starts mainly with the crystallisation of sodium chloride, followed by a complex mixture of magnesium and potassium salts. The precipitated salts are separated and further processed to produce commercial products. What is required is no longer just a profitable process; today, environmental compatibility, resource efficiency, and social aspects are also relevant criteria. The philosophy of K-UTEC intends to produce as many valuable by-products as possible, improving both resource efficiency and the robustness of the overall project economics to price and demand fluctuations of individual products. This approach improves the sustainability of our customers‘ projects and additionally minimises the disposal volumes of process outputs.

The magnesium-lithium ratio is an essential parameter for determining the subsequent process steps. For natural brines with a low magnesium-lithium ratio and thus little effort for magnesium separation, a commonly applied process variant for the separation of magnesium includes two process steps using lime (CaO) to separate the magnesium and, in a second step, soda ash ($Na_2CO_3$) to precipitate lithium carbonate ($Li_2CO_3$). If necessary, a product upgrading process is applied that uses $CO_2$ to redissolve the $Li_2CO_3$, followed by heating the lithium solution to recrystallise the $Li_2CO_3$ with the release of $CO_2$. In classical approaches, lithium hydroxide is indirectly produced from lithium carbonate by chemical conversion steps or electrochemical methods.

To avoid the production of highly concentrated brines in solar evaporation ponds in regions with low evaporation rates or lack of space, means may be reasonable to recover lithium as a lithium phosphate precipitate selectively. The lithium phosphate is converted to battery-grade lithium hydroxide by a chemical or electrochemical process. Due to the 30-fold lower phosphate solubility than carbonate, precipitation of lithium phosphate promises much higher primary yields than precipitation of lithium carbonate.

Most current processes using conventional solar evaporation followed by the soda-lime process achieve lithium recovery rates below 50%, although with careful process design and operation, much higher yields for lithium are achievable. K-UTEC has developed and demonstrated several significant achievements in this traditional process to eliminate the biggest obstacles, including improved process efficiency and overall environmental sustainability. For brines with a high magnesium-lithium ratio, where classical approaches lead to significant lithium losses, K-UTEC can use a proprietary and patented lithium chloride evaporative crystallisation process. With this process, lithium chloride can be directly separated, even from brines with high magnesium concentrations, without additional costly separation steps.

## Selected concrete achievements of the K-UTEC proprietary process know-how and technology are

- Increase the lithium recovery rate from below 50% to over 80% in solar pond application by minimising losses caused by adhering brine or crystallisation of lithium-bearing minerals without increasing freshwater consumption.
- A patented process for direct lithium chloride precipitation from brines with high magnesium concentrations, achieving high recovery rates without using expensive reagents or solvents.
- Significant improvement of downstream processes by applying proprietary reactor technology that enables control of grain size of the precipitate
- A proprietary technology based on electrodialysis for the direct precipitation of LiOH from LiCl brine without additional water or harmful reagents.

## Lithium separation from hard rock minerals by Concentrate and Acid Roasting

The traditional approach for lithium extraction from minerals such as Spodumene begins with a thermal decrepitation process of the Spodumene concentrate above 1000 °C. High temperatures induce converting the virtually acid-insoluble α-Spodumene phase into the acid-unresistant β-Spodumene forming water-soluble lithium sulfate after mixing with concentrated sulfuric acid and roasting at 200°C. After aqueous leaching, the use of lime (CaO) or limestone ($CaCO_3$) neutralises the solution causing the conversion of excess sulfuric acid into gypsum ($Ca_2SO_4 \cdot 2H_2O$) and precipitating various metal hydroxides, which are separated from the slurry by filtration. Admixing soda ash to the purified leach solution and finishing procedures precipitate lithium carbonate, separated, washed, dried, and packed.

## Lithium Extraction from Clays and Micas

Leaching properties of clays and micas depend on physical factors like grain size distribution and chemical factors like crystalline structure, cation exchange capacity (CEC), and the chemical composition of any solution in contact with the mineral. To effectively leach lithium from clays with mineral acids, a significant excess of acid and the application of high temperatures and appropriately long residence times are required. Thus, a subsequent neutralisation is mandatory. Because of the cations present in the clay, the effort to purify the leaching solution can be substantial, resulting in an overly complicated and costly process. Other processing concepts use additives and calcining procedures to convert the lithium bound to silicates into water-soluble salts.

## The K-UTEC approach for lithium-bearing minerals

K-UTEC follows the approach of calcining to minimise environmental impacts and to reduce the use of sulfuric acid and other operational costs. The application of reagents such as sulphates of alkali salts is balanced, and thus the need to neutralise the leaching solution is reduced to a minimum or even totally avoided. Furthermore, K-UTEC has developed an extraction process based on ore calcination with sulfate carriers and other mineral-specific additives, followed by water leaching. This process has proven excellent recovery rates for a wide range of lithium-bearing minerals and minimises environmental impacts and operation costs by avoiding acids and subsequent neutralisation. Excessive purification steps are not required to produce lithium carbonate or lithium hydroxide from the leaching solution.

## Direct Lithium Extraction, DLE

A DLE process uses a lithium-selective sorbent to separate lithium from other ions present in the feed solution. Over the past decade, many DLE technologies have arisen due to intense research concerning the testing and development of organic and inorganic sorption reagents for achieving a high selectivity specific to lithium in complex aqueous solutions. Sorbents based on manganese and aluminium hydroxide-oxides continue to form the backbone of lithium extraction technologies and have already found their way to the first industrial lithium projects in China and Argentina. A second and third generation of liquid-liquid extraction technology, absorbents, and ion exchange materials with higher selectivity and improved chemical, thermal and mechanical stability are the subject of current testing at laboratory and pilot plant scales. However, many experimental DLE technologies showing promising results at a laboratory scale fail when applied at a larger scale. Only a few DLE technologies have proven successful after their implementation into an industrial scale process in brine projects until now.

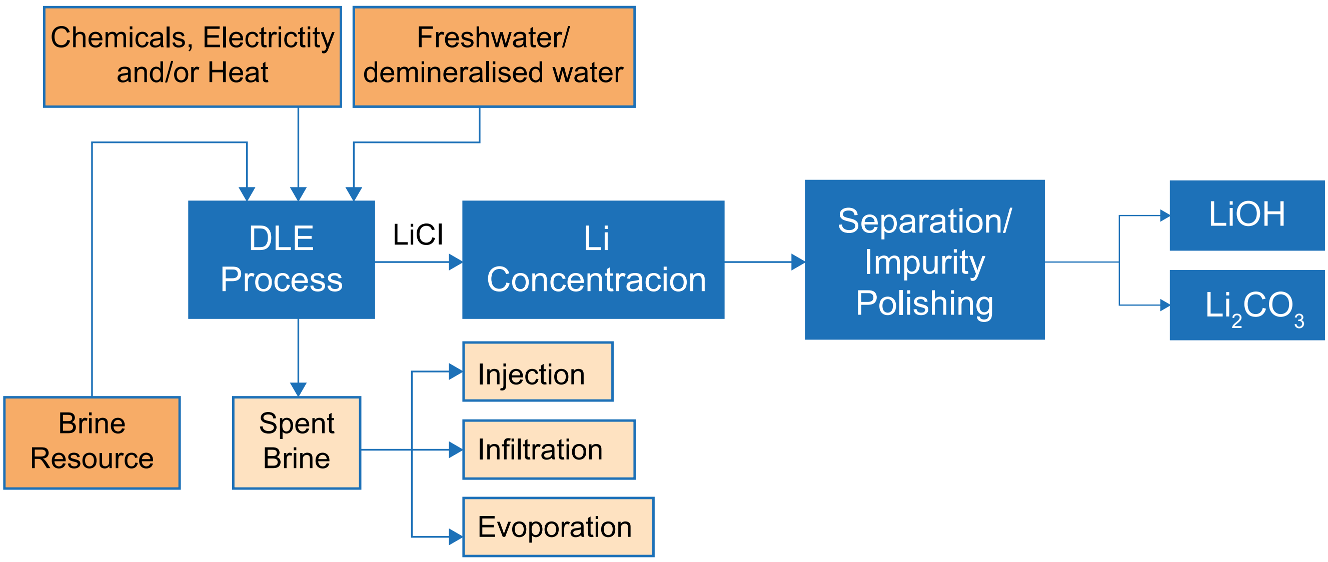



*Figure: General DLE Process applied to brines*

K-UTEC cooperates with leading technology partners and includes promising technologies in its overall process development and pilot plant trials to assess their potential technical, environmental, and economic benefits in industrial-scale lithium projects combined with K-UTEC's membrane technologies as electrodialysis for direct Lithium hydroxide production e. g. based on LiCl brine resulting from DLE applications.

## Pros & Cons of DLE

The following table summarises the potential advantages and limitations of using DLE technologies for brines compared to the traditional evaporation- crystallisation processes.

## Potential Advantages of DLE

- Facilitation of the downstream process after DLE compared to the traditional procedure
- Shortening of the brine residence time compared to the traditional process.
- Reduction of required lithium inventory, compared to the traditional procedure.
- Low weather and environmental conditions (rainfall, evaporation rate, altitude, etc.) sensitivity of the operation.
- Frequently rejects critical impurities, yielding a higher quality product that sells at a premium to lower grade.

## Potential Limitations of DLE

- Practical proof of robustness and reliability of most DLE technologies in industrial practice over long periods is still lacking (chemical, thermal, and mechanical stability of adsorbent materials or membranes);
- Higher energy demand compared to traditional method
- Occasionally higher initial and ongoing CAPEX and/or OPEX costs according to specific project settings; increased demand for maintenance, logistics, and trained staff.
- Sherry picking approach usually only takes advantage of lithium in the brine and neglects other valuable products, such as potassium, magnesium, boron, or bromine salts.
- Lithium desorption from adsorption or ion exchange resins usually requires flushing with mineral acids, deionised water, or highly concentrated salt solutions, which increases costs and logistic requirements; desorption processes applying heated water can avoid the use of chemicals but require high energy input.
- Trace levels of residues of extractant material in spent brine eluates might impede a direct reinjection in the subsurface without additional treatment steps.


## OUR TECHNICAL CENTER

Our pilot plant area, equipped with process engineering facilities for a flexible design that allows for testing complete production processes, covers more than 1,500 square meters. In our near-industrial demonstration plant, many tons of raw materials are processed into the desired end products.

The demonstration of complete processes in continuous operation gives our customers and their financing partners the necessary investment security, provides test samples for early marketing of the planned products, and enables our customers' employees to be professionally trained and qualified even before a plant is commissioned. This measure largely avoids unexpected complications during commissioning.

The process technologies that can be tested in the pilot plant range from comminution and classification of the raw materials to mechanical separation processes and solar or technical evaporation or crystallisation processes for complex brines, including drying and compacting the end products. A special focus lies in the application of new processes for direct lithium extraction (DLE).

Featured services provided by the Technical Center:

- Practical testing of solar evaporation procedures in solar ponds, applying site-specific climate conditions in an indoor test system equipped with a climate-controlled chamber (sub-zero to desert conditions), combined with mathematical modeling of crystallisation behavior and thermodynamic behaviour parameters.
- Process optimisation studies to improve lithium recovery rates, product quality, and to minimise environmental impacts (water, energy use, waste generation, $CO_2$ footprint).
- Pilot plant for selective liquid-liquid lithium extraction for process development and optimisation of extraction process, concentration, impurity polishing and battery quality lithium carbonate and hydroxide crystallisation.
- Testing and optimisation of process integrated or standalone direct lithium extraction (DLE) technologies.
- Fractional crystallisation of simple and complex salts through solar and/or industrial evaporation processes.
- Comminution and classification by crushing and grinding of raw materials with jaw crusher, roller mill, impact mill, agitator bead mill, screening.

## Achieving the best for our customers…

…has always been our objective. To this end, we design plants to enable our clients to produce all possible valuable products at the required quality, in the highest possible quantities, at the lowest possible production cost and at the same time with the lowest environmental impact.

Our professional team includes two „Qualified Persons“ according to internationally recognised standards (CRIRSCO, NI 43 101, JORC) for GEO-disciplines and two Qualified Persons (FIMM) for Process Engineering who monitor, review and approve our feasibility studies, converting them into official documents accepted by banks and the stock exchange.

## Process development & plant design

Our specialists develop, engineer, and realise plants providing the high capability to convert a wide range of raw materials into valuable products for the chemical, mineral processing and fertilizer industries, using state-of-the-art process technology approved by our Qualified Persons.

### Raw materials

- Inorganic mineral raw materials with a particular focus on raw salts of oceanic or evaporitic origin
- Saline solutions of natural or industrial origin and solution mining.
- Seawater, brines and bitterns from seawater evaporation or sea salt production.
- Saline solutions of anthropogenic origin, particularly industrial process waters and sewage.
- Raw materials containing strategic energy metals, in particular lithium, copper, and cobalt compounds, as well as rare earth elements and germanium
- Solid wastes and industrial residuals with a significant concentration of inorganic valuables, e.g. from the recycling of batteries or hydroxide sludges, electrolyterecycling
- Metal-containing wastes and residual materials of magnesium, aluminium, and copper recycling

### Process steps

- Mechanical processing by grinding, crushing, screening
- Flotation
- Ion-selective separation processes (solvent extraction, membrane, ion exchange, adsorption)
- Fractional crystallisation of single salts or salt mixtures through solar evaporation, industrial evaporation processes or other concentration processes based on water removal
- Hot leaching processes with subsequent cooling crystallisation
- Decomposition of double and triple salts
- Controlled precipitation (in particular grain growth, shape and size) of products and for brine cleaning as a continuous process
- Brine cleaning with ion exchangers
- Electrolysis
- Solid/liquid separation by filtering, centrifuging, thickening, purification and sedimentation.
- Drying and compaction of end products.

### Products

- Potassium chloride (KCl) and potassium sulphate ($K_2SO_4$) as fertilisers or industrial salts (sylvite, MOP, KCl 98/99, SOP).
- Sulphate-containing double salts (picromerite, leonite, langbeinite, kainite), Kali Magnesia.
- Magnesium compounds such as magnesium carbonate ($MgCO_3$), magnesium chloride ($MgCl_2$), Magnesium sulphates ($MgSO_4$), magnesium hydroxide (MgOH, MDH),
- Magnesium oxide (MgO, CCM, DBM).
- Sodium chloride (NaCl) in food and industrial salt quality
- Sodium sulphate as Glauber salt or anhydrous sodium carbonate.
- Calcium carbonate ($CaCO_3$), calcium chloride ($CaCl_2$), calcium sulphate as plaster, anhydrite or hemihydrate.
- Aluminium hydroxide, aluminium oxide, alum, aluminate.
- Boric acid, pentaborate, borax (e.g. from ulexite).
- Salts of energy metals, in particular lithium compounds ($Li_2CO_3$, LiOH, $Li_2SO_4$, LiCl, LiF, etc.), copper- and cobalt-, as well as nickel-containing salts, germanium, and salts of rare earths.

# SELECTED LITHIUM PROJECT REFERENCES

| Project | Location / Client | Size | Year | Remarks |
|---|---|---|---|---|
| Scoping Study and Pilot Plant Test Work for the extraction of LiCl from brine by ADIONICS's TSSA technology and subsequent production of LiCl and LiOH | Service for global players in Chile and Argentina | | 2022 | Pilot Plant runs in cooperation with Adionics Advanced Ionic Solutions; scoping studies using natural and preconcentrated brines |
| Production of lithium hydroxide monohydrate based on Li bearing ore pertaining to the Las Navas project | Cáceres, Spain/ LITHIUM IBERIA S.L., Spain | 35 kt/a LHM<br>50 kt/a SOP | 2021 | Scoping study |
| Investigations for Valjevo Lithium-BorateProject | Serbia; EURO LITHIUM INC./ Canada | 20 kt/a LCE<br>350 kt/a $H_2BO_3$ | 2021 | Scoping study |
| Production of lithiumhydroxide based on calcined Zinnwaldite | Zinnwald-Georgenfeld/ Altenberg, Germany/ Deutsche Lithium GmbH/ Germany (former Solar-World) | 8.5 kt/a LHM<br>40 kt/a SOP | 2021 | Process design and extended process design including test work (lab andpilot tests) and cost estimation |
| Production of lithiumhydroxide based on lithium carbonate | Global eEnergy Solutions LLC, USA | 20 kt/a LHM | since 2020 | Engineering services |
| Recovery process of valuable elements contained in residual brine resulting from YLB's salar operations | Uyuni, Bolivia/ACI Systems Alemania GmbH, Germany | 39 - 46 kt/a LHM<br>340 - 345 kt/a $Mg(OH)_2$ | 2018 | Scoping study ontheoretical basis |
| Improvement of selected process sections within the recovery of lithium brine and MOP from Atacama brine | Service for a globalplayer | | 2018 | Engineering services |
| Extraction of lithium andother valuable components based on clay | Khukh Del Lithium Deposit, Mongolia/Kazzinc LTD, Kazakhstan | 22.8 kt/a LCE<br>160 kt/a SOP | 2018 | Scoping study |
| Production of lithium salts based on calcined Zinnwaldite | Deutsche Lithium GmbH/ Germany | 5 kt/a LiF<br>0.8 kt secondary LiF 24 kt/a SOP | 2018 | Pilot tests and processdesign |
| Process evaluation andimprovement of lithium recovery rates at two different sites | Service for a globalplayer | | since 2016 | |
| Production of lithium carbonate based on mixed salt obtained after solar evaporation | Salar de Uyuni, Boliovia/ COMIBOL-GNRE, Bolivia | 30 kt/a LCE | 2015 - 2017 | Basic and detail engineering including testwork and cost estimation |
| Utilisation of natural brine to recover potash, borate and lithium carbonate | Salar de Jama, Argentina/ CUPER, Argentina | 350 kt/a NaCl<br>2 kt/a $Li_2CO_3$<br>14 kt/a $K_2SO_4$<br>12 kt/a $H_3BO_3$ | 2014 | Scoping study ontheoretical basis |

| Project | Location / Client | Size | Year | Remarks |
|---|---|---|---|---|
| Manufacture of lithium carbonate from a Hectorite containing ore | Western Lithium Corp, Vancouver, Canada | 13 kt/a of $Li_2CO_3$46 kt/a $K_2SO_4$<br>72 kt/a $Na_2SO_4$<br><br>3 kg/h of $Li_2CO_3$<br>11 kg/h $K_2SO_4$<br>12 kg/h $Na_2SO_4$ | 2011 - 2016 | Process design<br><br>Design, engineering, construction and operationof a demonstration plant |
| Production of lithium carbonate and potassium sulphate based on Zinnwaldite | Zinnwald-Georgenfeld/ Altenberg, Germany / SolarWorld, Germany | 4.9 kt/a LCE<br>3.8 - 7.4 kt/SOP<br>30 kt/a Glauber's salt | 2012 - 2013 | Scoping design on atheoretical basis |
| Production of $Li_2CO_3$ based on waste streamsfrom ETI BPH plants | ETI MINE WORKS, Turkey | 5 kt/a of $Li_2CO_3$ | 2012 | Consultancy, assessment and discussion of information provided by ETIMines inclusive visual inspection of BPH plants owned by ETI |
| Resource efficient recovery process of potash, borates and lithium salts from naturalbrines (Salinas Grandesbrine, Argentina) | Deutsche Bundesstiftung Umwelt (DBU), Germany | 7 kt/a LiCl | 2010 - 2015 | Research project including comprehensive test work program followed by process design and cost estimation |
| Integrated utilisation of natural brine to recover NaCl, KCl and LiCl resp. $Li_2CO_3$ and borates | Salar de Salinas Grandes, Argentina / Sales de la Puna, Argentina | 2 kt/a LCE<br>14 kt/a SOP<br>12 kt/a $B_2O_3$ | 2007 - 2011 | Technological investigation |
| Extraction of lithium, potash and boron fromnatural brine | Salar de Uyuni, Bolivia / ERAMET, France | 20 kt/a LCE | 2009 | Theoretical investigations |
| Separation of LiCl and NaCl by means of fractional crystallisation | Chemetall, Germany | | 2008 | Investigation onoptimisation |
| Recovery of KCl, $K_2SO_4$,NaCl and LiCl resp. $Li_2CO_3$ and borates based on natural brine | Salar del Rincon, Argentina / Admiralty, Australia | 15 kt/a LCE | 2006 | Process design and feasibility study |
| Crystallisation of $LiClO_4$ | Chemetall, Germany | 2 kt/a Li-Perchlorat | 2004 | Investigation onoptimisation |
| Recovery of lithium saltsfrom natural brines and crystallisation of $Li_2CO_3$ | supported by Governmental grants | | 1999 - 2005 | Several research projects |
| Investigations for lithiumtechnologies based on German and South American deposits | performed by former KFI (Kaliforschungsinstitut of GDR) | | 1955 - 1990 | |

**Glossary:**
LHM – lithium hydroxide monohydrate
LCE – lithium carbonate equivalent
SOP – potassium sulfate
MOP – potassium chloride
Glauber Salt – sodium sulfate
MDH – magnesium hydroxide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