Empowering electromobility

Sustainable lithium production from brine to battery

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June 1, 2024

COMPANY INTRODUCTION

KBR at a Glance

$7.0 B

Revenue
Full year 2023

Headquarters

Houston
Texas, USA

KBR delivers science, technology and engineering solutions to governments and companies around the world.

Drawing from its rich 100-year history and culture of innovation and mission focus, KBR creates sustainable value by helping clients meet their most pressing challenges today and into the future.

~34,000

Employees

Global Presence

80+
Countries

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Our Businesses

GOVERNMENT SOLUTIONS

SUSTAINABLE TECHNOLOGY SOLUTIONS

We deliver science, technology and engineering solutions to governments and companies around the world.

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Sustainable Technology Solutions: Core Capabilities

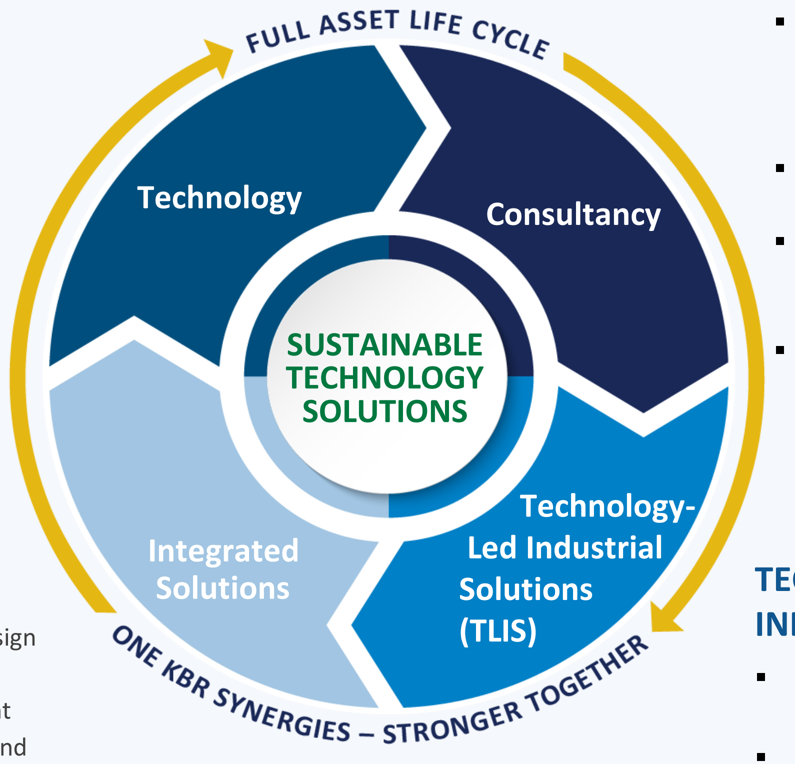
~7,000
EMPLOYEES

3 GLOBAL HUBS
IN HOUSTON, LONDON AND INDIA SUPPORTED BY REGIONAL OFFICES

>80
DIFFERENTIATED TECHNOLOGIES

TECHNOLOGY

- Leading global provider of innovative, sustainable licensed technologies and catalysts
- Broad and expanding portfolio of technologies, enabling growth industry cycles



CONSULTANCY

- Specialist Consultancy Group with primary pillars: Project development, energy efficiency, decarbonization, technical M&A support
- Execution of projects from feasibility through to Pre-FEED
- Industry specialist in development of execution, contracting and O&M strategies
- Execution of technology assessment and configuration studies

INTEGRATED SOLUTIONS

- Cutting-edge, digitally-enabled design and engineering
- Best-in-class program management
- Extensive capabilities in complex and remote environments

TECHNOLOGY-LED INDUSTRIAL SOLUTIONS

- Digital, artificial intelligence, predictive analytics and machine learning solutions
- Leveraging human performance and remote operations expertise
- Optimizing existing operating assets across a wide installed base, including LNG and ammonia, to increase production and reduce emissions

- SUSTAINABILITY AND ENERGY TRANSITION FOCUS
- LEADING-EDGE DIGITAL TOOLS
- DATA CENTRIC APPROACH
- OPTIMIZED BLEND OF CAPEX AND OPEX
- EFFICIENT OPERATING MODEL
- HIGH-PERFORMING AND INNOVATIVE CULTURE
- AN INCLUSIVE AND DIVERSE WORKPLACE

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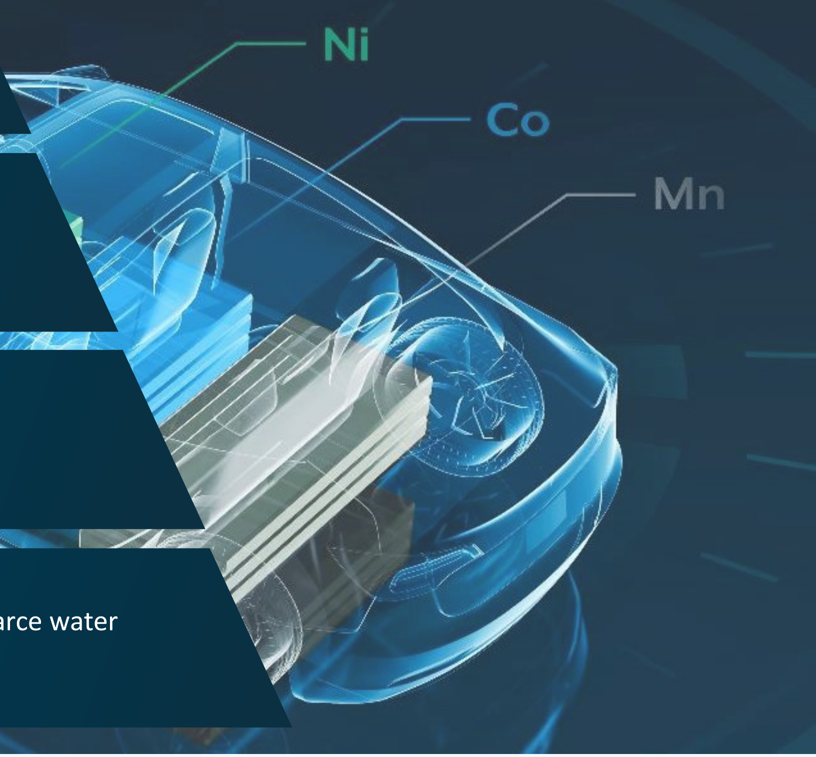
KBR Technology Portfolio – Critical Minerals

PureLi℠- High-purity lithium production technology	Unique lithium conversion and refining process to transform a variety of lithium feedstocks into battery-grade lithium carbonate or lithium hydroxide monohydrate
MetEx℠ - Battery metal extraction & purification	Extraction and purification technology that recovers battery metal salts from various feedstocks, including ore concentrates, spent electrolytes, and e-waste
Titanium Dioxide	Black liquor crystallization and spent acid recovery technologies Ensures overall efficient and sustainable production process
Phosphoric Acid & REE	Wet phosphoric acid concentration and purification systems for any capacity Conversion and refining of REE salts and recovery of inorganic acids
Zero Liquid Discharge	Versatile applications to manage issues of scarce water reserves and natural resource depletion

Evaporation and Crystallization



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KBR Technology Portfolio – Critical Minerals

Nitric Acid

- Up to 99% HNO3 using
  - Magnesium Nitrate (MAGNAC®)
  - Sulfuric Acid (NACSAC®)
- Up to 68% HNO3 by rectification (NAPC®)

Hydrochloric Acid

- Pre-concentration up to 24 % HCl
- Medium concentration up to 35 % HCl
- High concentration up to 100 % HCl
- Purification

NOx absorption

- Down to 20 ppm NOx (with additional treatment)
- Using water and atmospheric air only
- Recovery of HNO3
- Atmospheric or under pressure

ACID CONCENTRATION AND PURIFICATION

Sulfuric Acid

- Pre-concentration at atmospheric or under vacuum conditions
- Medium concentration up to 85% H2SO4 at vacuum conditions
- High concentration up to 98% H2SO4, at vacuum conditions and high temperature

Mixed Acids

- Separation
- Purification
- Concentration

NB and NCB

- With integrated energy recovery
- Minimized by-products
- Compact unit with integrated SAC®
- Use of weak nitric acid feedstock

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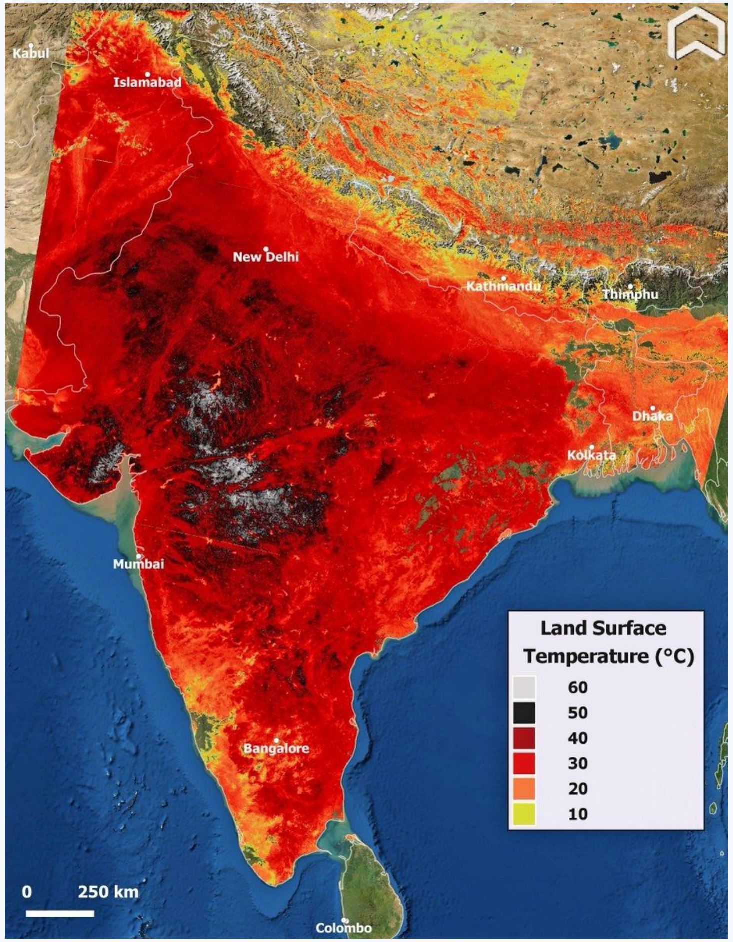
MOTIVATION

Heat Wave in India





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Climate Change

Fossil fuels – coal, oil and gas – are by far the largest contributor to global greenhouse gas emissions.

As greenhouse gas emissions blanket the Earth, they trap the sun’s heat, leading to global warming and climate change.

To limit global warming to 1.5°C, emissions need to be reduced by 45% by 2030 and reach **net zero** by 2050.

Transitioning to a net-zero world is challenging and requires the replacement of fossil fuels with energy from renewable sources.

To reach the net-zero target, many countries have started banning conventional cars or implementing 100 % sales of **electric vehicles (EVs)**.

Electromobility

Electric car markets are seeing exponential growth as sales exceeded **10 million in 2022**

More than half of the electric cars on roads worldwide are driven in **China**

In Europe, more than **one** in every **five** cars sold in 2022 was **electric**

Analysts expect **EV growth** to reach around **220 million by 2030**

National policies and **incentives** will support the trend, while high oil prices will further motivated prospective buyers

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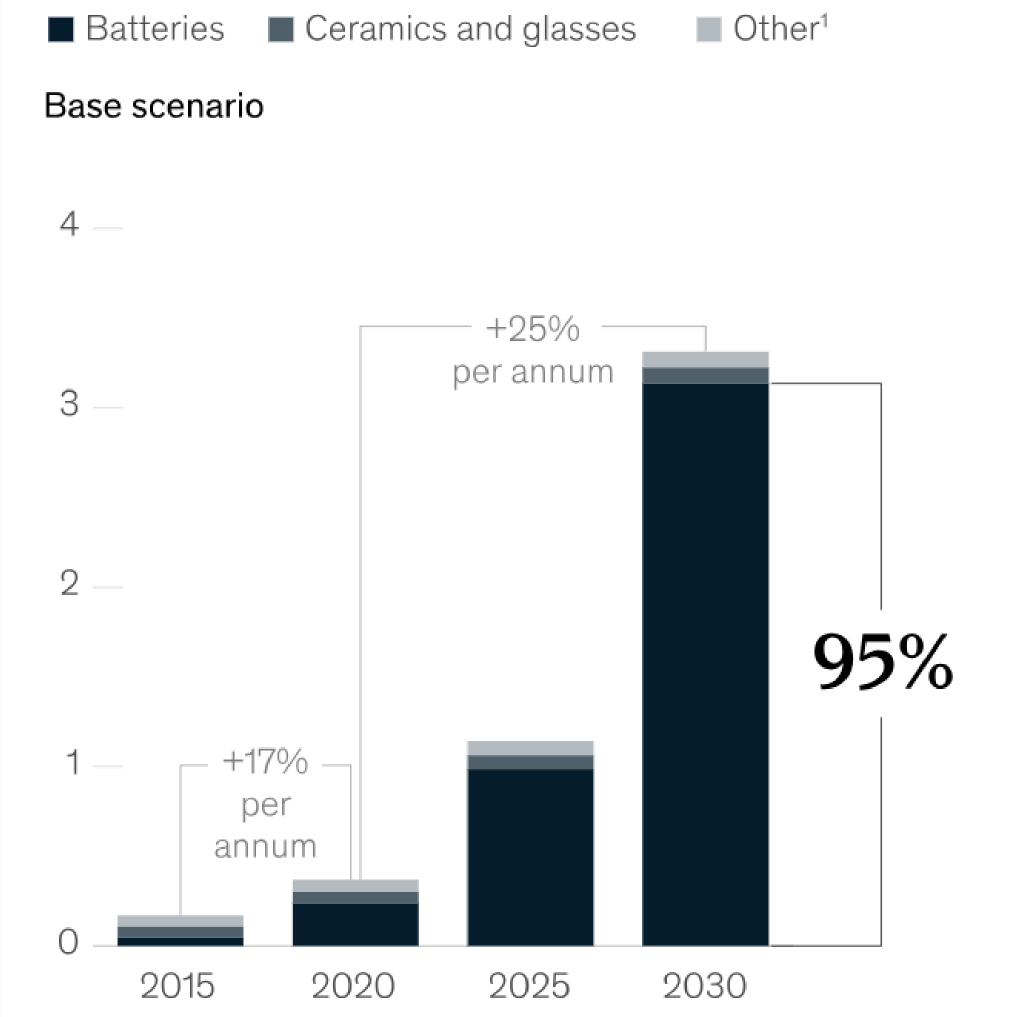
Market Trends

Global lithium demand by end use in MMt LCE

- Most of today's all-electric vehicles use **lithium-ion batteries**
- Lithium is used throughout lithium-ion batteries, mainly as **cathode active materials**
- Cathode active materials can be synthesized either via the carbonate or the hydroxide process route
- The main commercial products are:
  - Lithium Carbonate (LC)
  - Lithium Hydroxide Monohydrate (LHM)
- Current base-case analysis sees lithium demand of **3.3 MMt** in 2030, or a **CAGR** of **25%**



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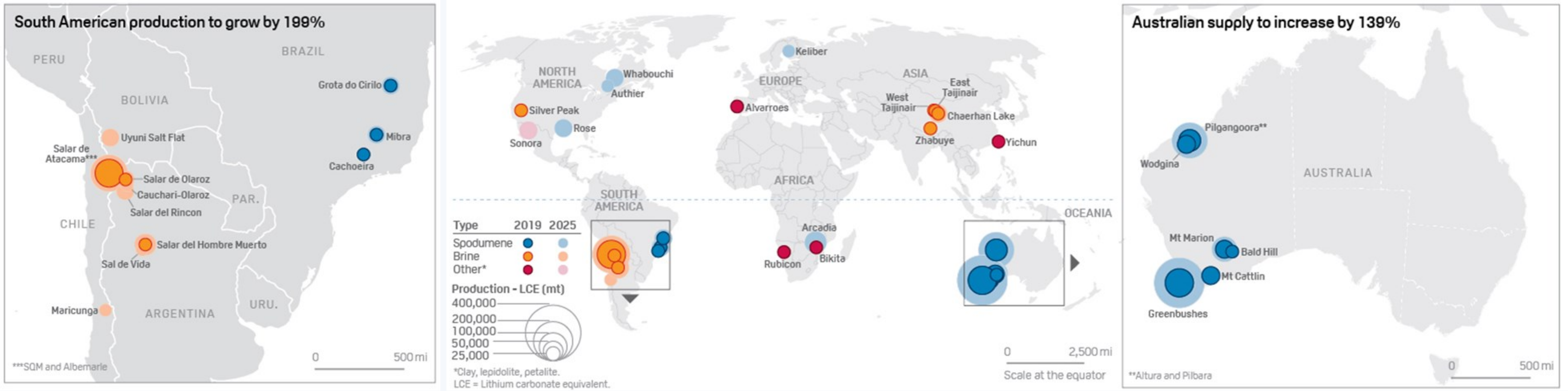
Key Geographies and Supply Chain

- Almost all lithium is currently obtained from either lithium chloride **brines** or from hard-rock **spodumene**, with the bulk of lithium resources coming from two key geographies, **South America** and **Australia**.
- In 2019, Australia exported about 1.6 million tons of spodumene-concentrate, with more than **95%** destined to **China**. Chile exported 82,344 tons of lithium carbonate, with South Korea being the largest importer in that year.
- China is dominating the **conversion and refining** of lithium concentrates and intermediates, capturing the largest shares of value-added along the global lithium value chain.



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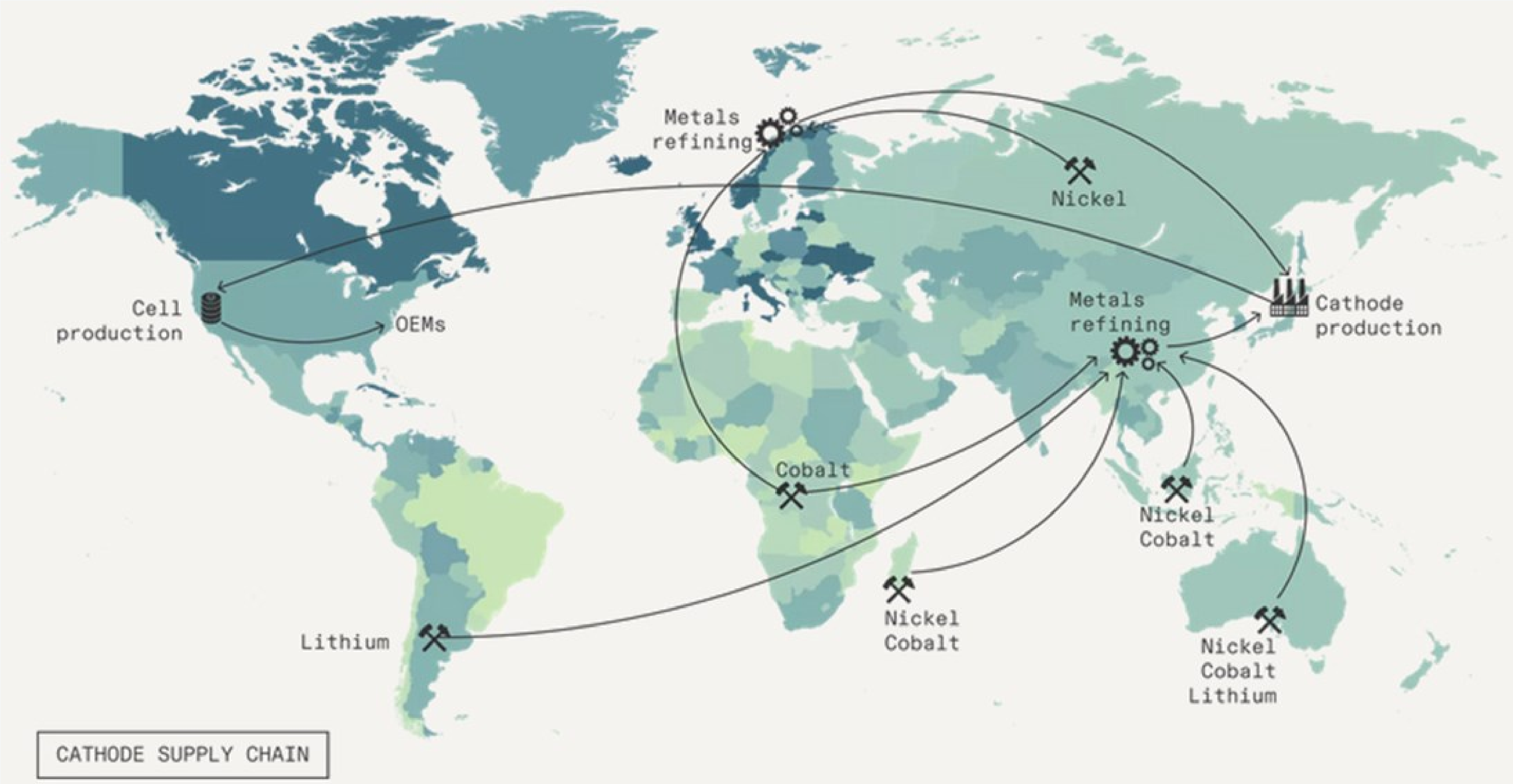
Key Geographies and Supply Chain

Unsustainable Supply Chain: Battery metals refining mainly in China



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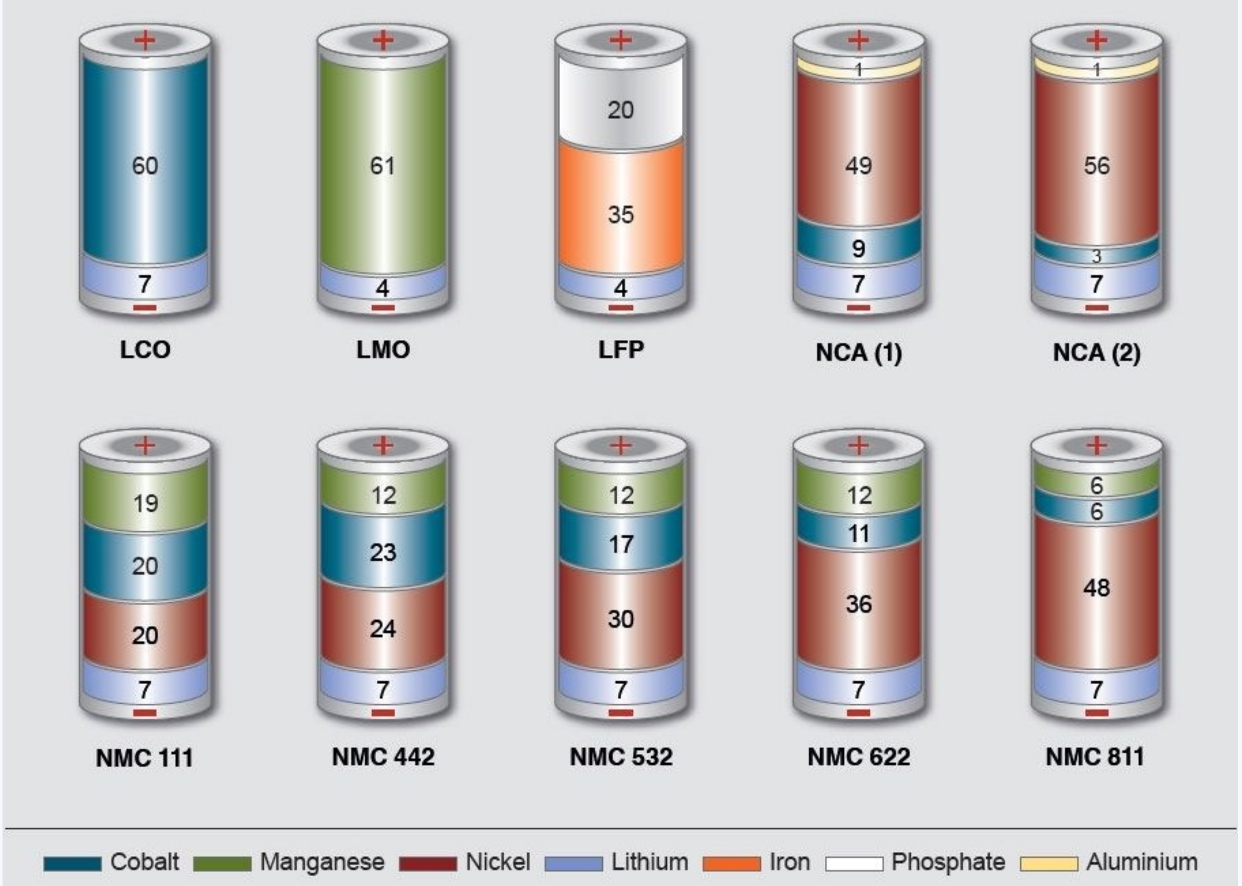
Cathode Active Materials



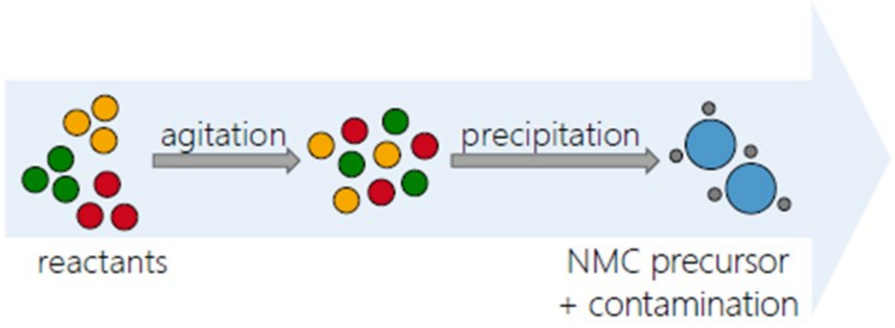
There are multiple cathode materials to choose from within the Lithium-ion battery space, such as cobalt (C), manganese (M), and nickel (N).

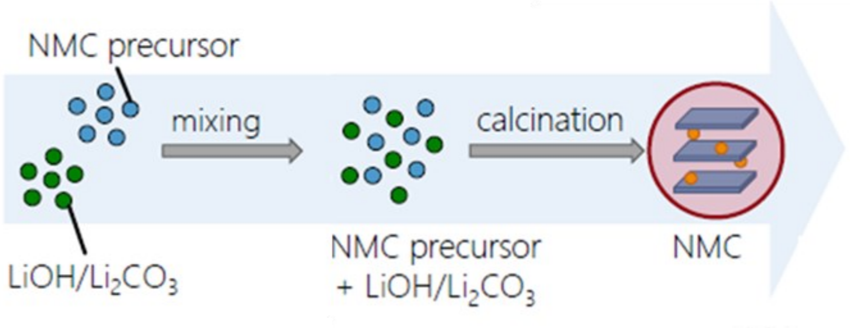
Originally, the primary active component of the cathode was cobalt. Today, cobalt is frequently being substituted out, partially with nickel (Hi-Ni cathode).

Cathode materials require **extremely high purity** levels and must be almost entire free of unwanted metal impurities.

Crystallization is essential to reliably produce high-purity materials from low-quality sources.

Cathode Active Materials – NMC





preparation of the hydroxide precursor

- $NiSO_4$, $MnSO_4$, $CoSO_4$ → coprecipitation (+ NaOH, + NH_4OH) → filtration & washing → drying

↓

$Ni_xCo_yMn_{1-x-y}(OH)_2$

↓

solid state synthesis to Li-NMC

- mixing (+ LiOH / Li_2CO_3) → calcination → grinding & classifying

↓

$LiNi_xCo_yMn_{1-x-y}O_2$

LITHIUM CONVERSION & REFINING PROCESSES

Product Specification

Technical grade LC specification (in wt.-%):

Li_2CO_3	Na	Ca	K	Fe	Pb	SO_4	Cl
≥99.0	≤0.1	≤0.01	≤0.01	≤0.002	≤0.002	≤0.2	≤0.005

Battery grade LC specification (in wt.-%):

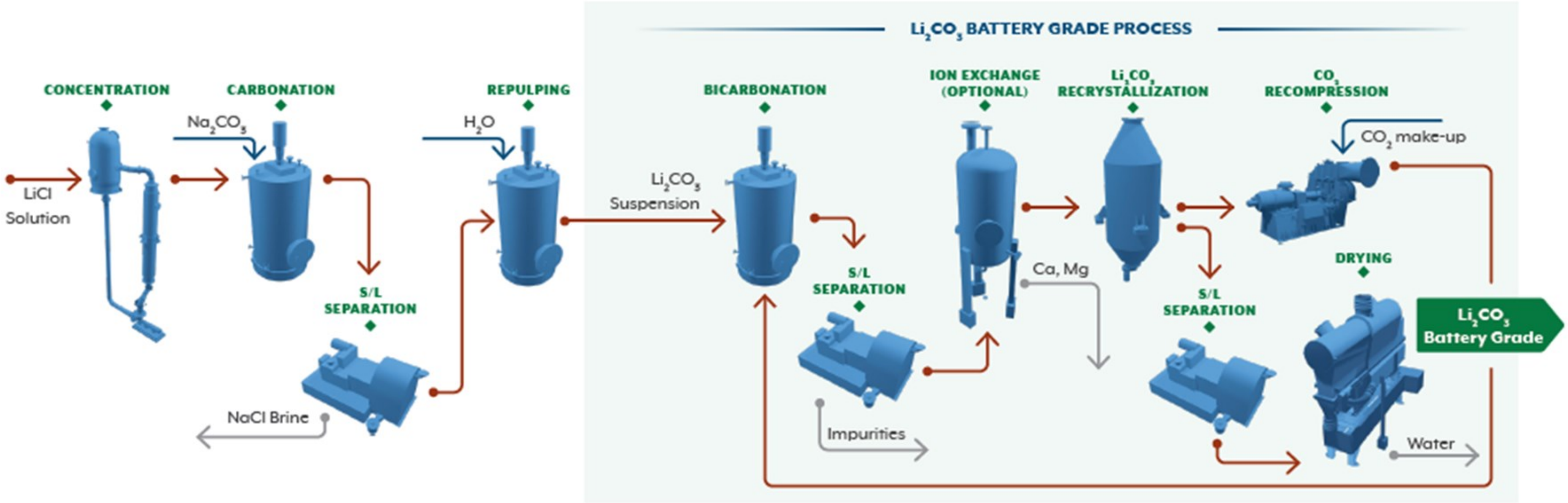
Li_2CO_3	Na	Ca	K	Fe	Pb	SO_4	Cl
≥99.5	≤0.025	≤0.005	≤0.001	≤0.001	≤0.0003	≤0.08	≤0.003

Battery grade LHM product specification (in wt.-%):

LiOH	Na	Ca	K	Fe	CO_2	SO_4	Cl
≥56.5	≤0.002	≤0.0015	≤0.001	≤0.0005	≤0.35	≤0.01	≤0.002

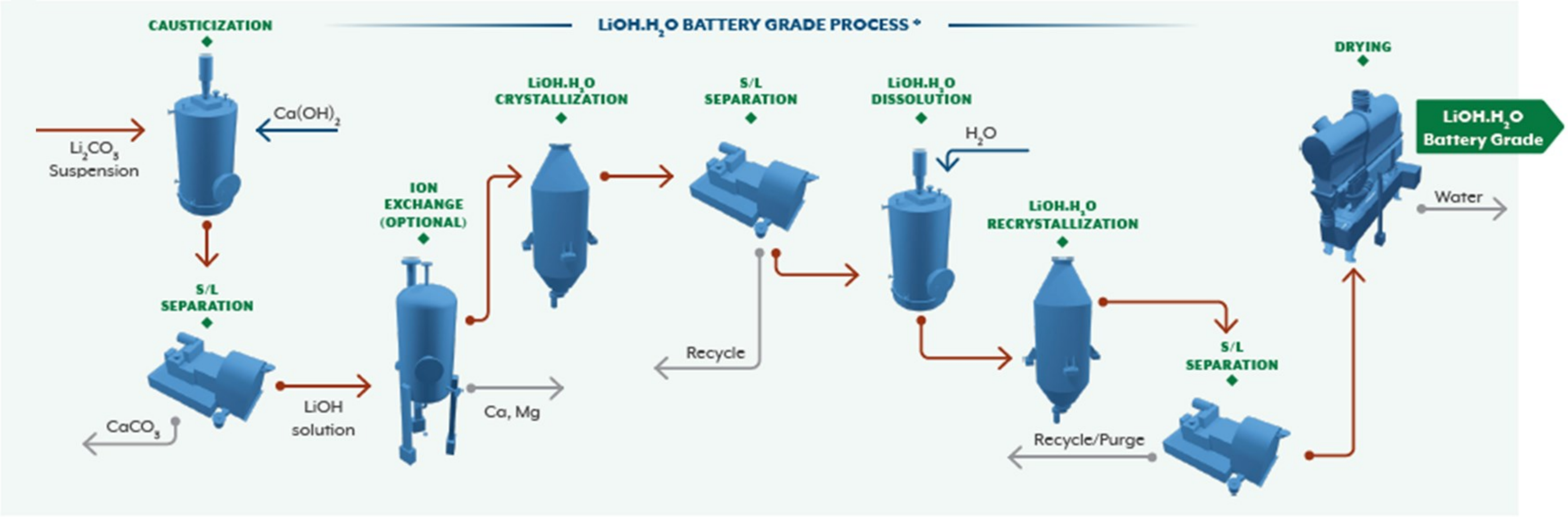
KBR's PureLi℠ Technology

- Battery-grade lithium carbonate from lithium chloride solution



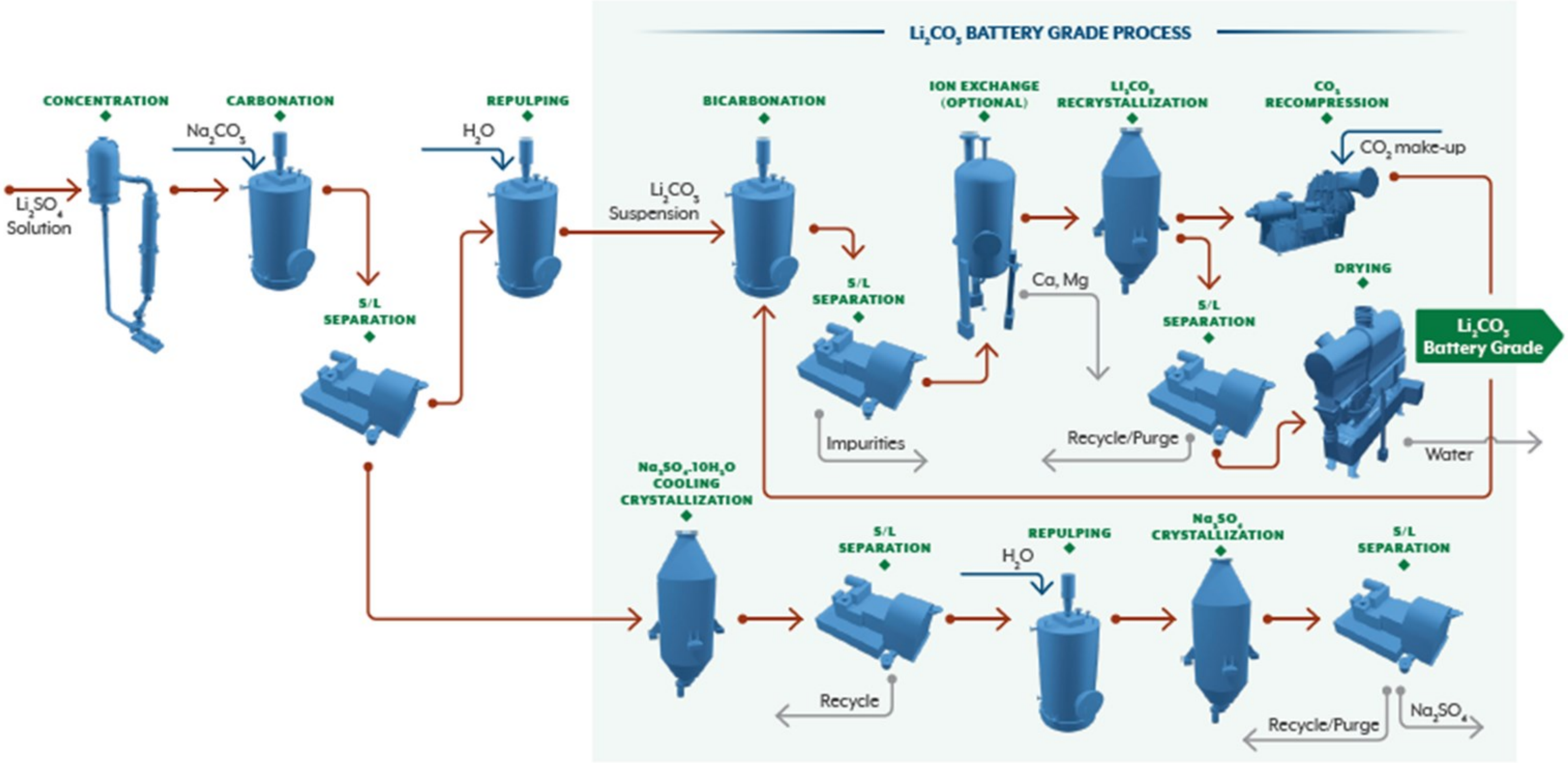
KBR's PureLi℠ Technology

- Battery-grade lithium hydroxide monohydrate from lithium carbonate suspension



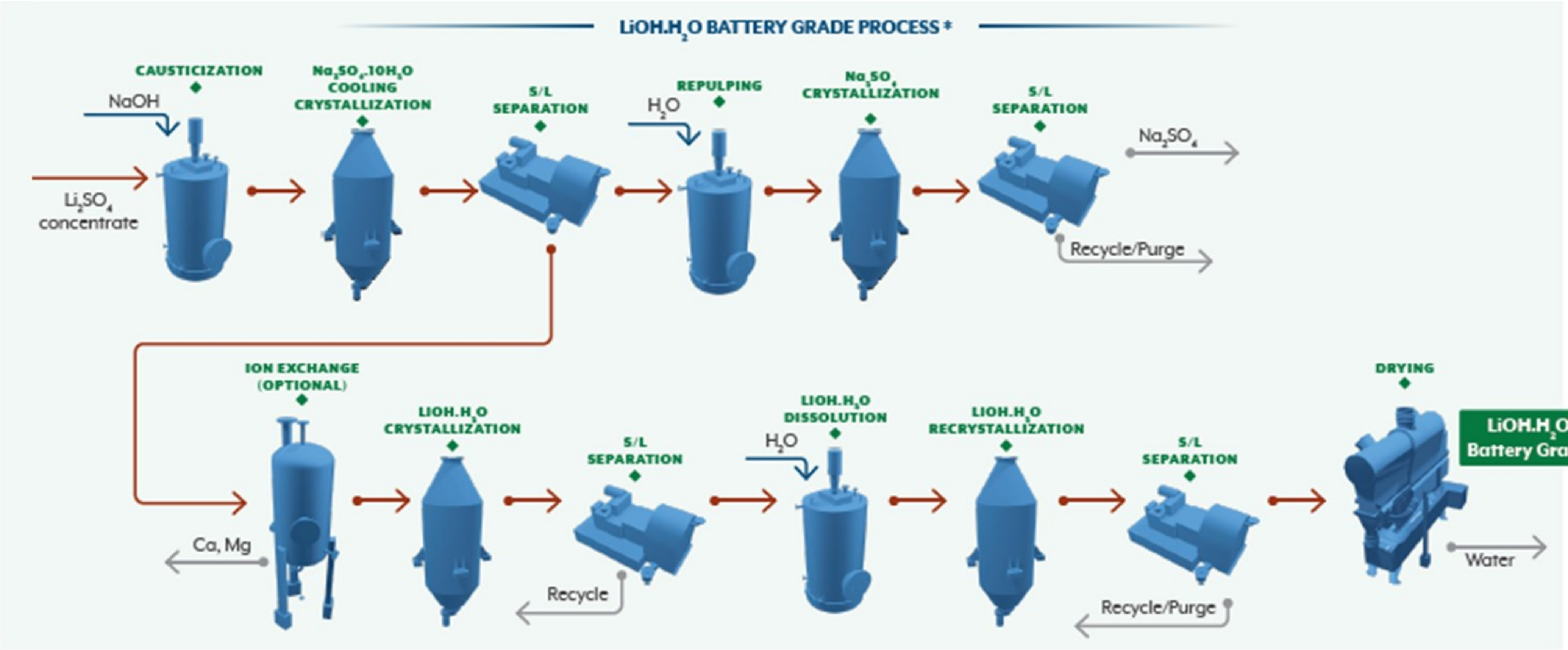
KBR's PureLi℠ Technology

- Battery-grade lithium carbonate from lithium sulfate solution



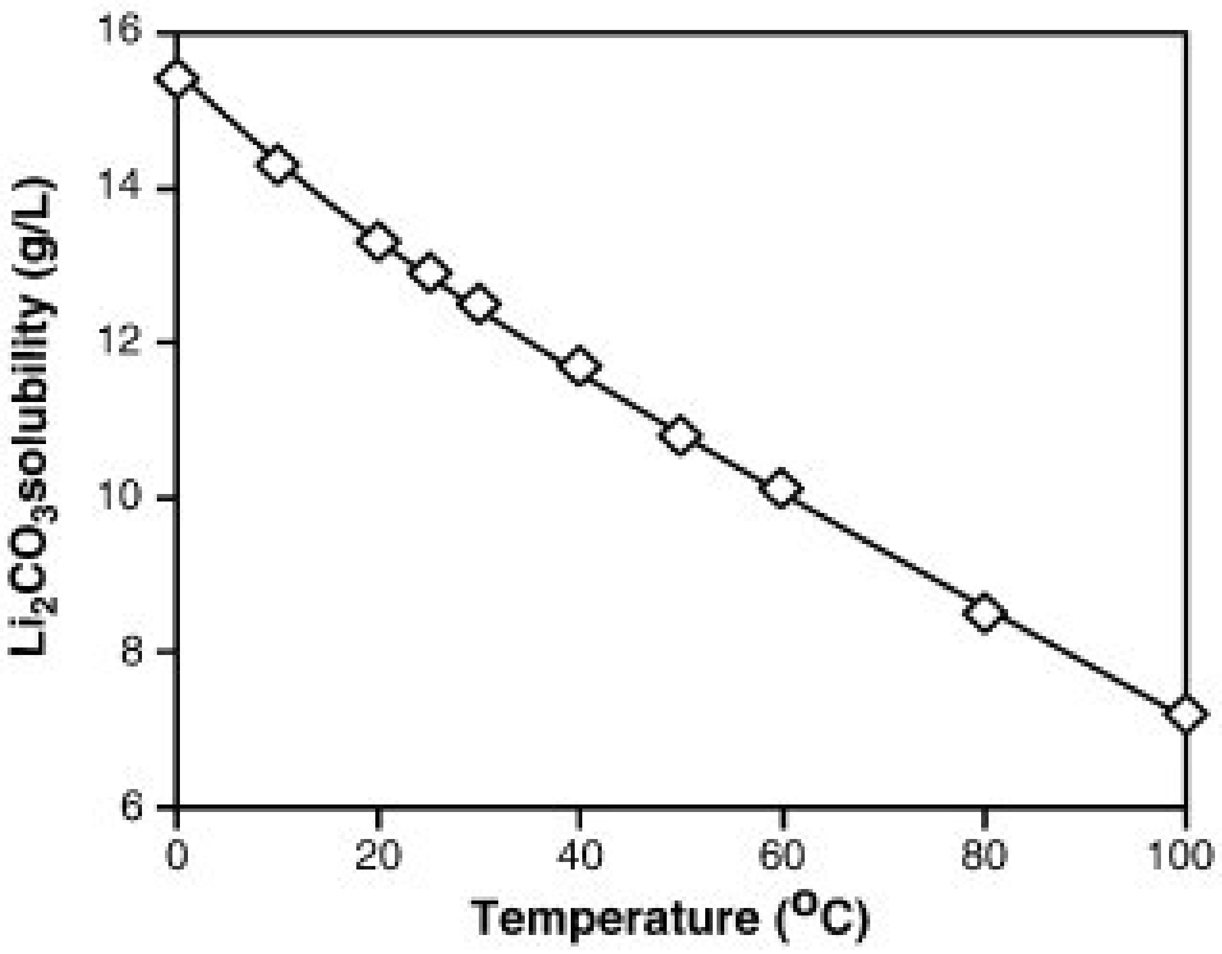
KBR's PureLi^{SM} Technology

- Battery-grade lithium hydroxide monohydrate from lithium sulfate concentrate



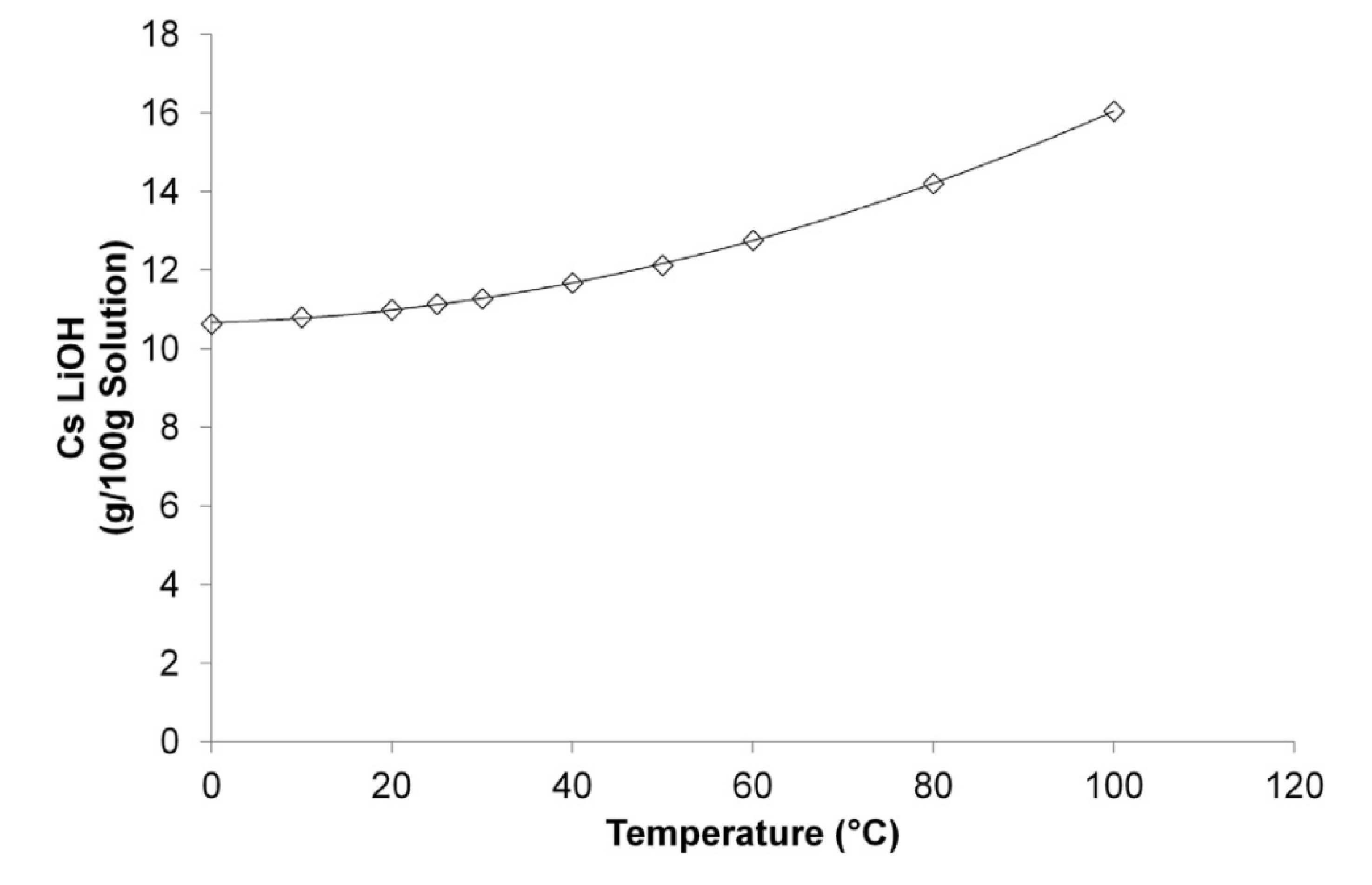
Solubility Diagrams

Solubility of lithium carbonate in water



Solubility Diagrams

Solubility of lithium hydroxide in water



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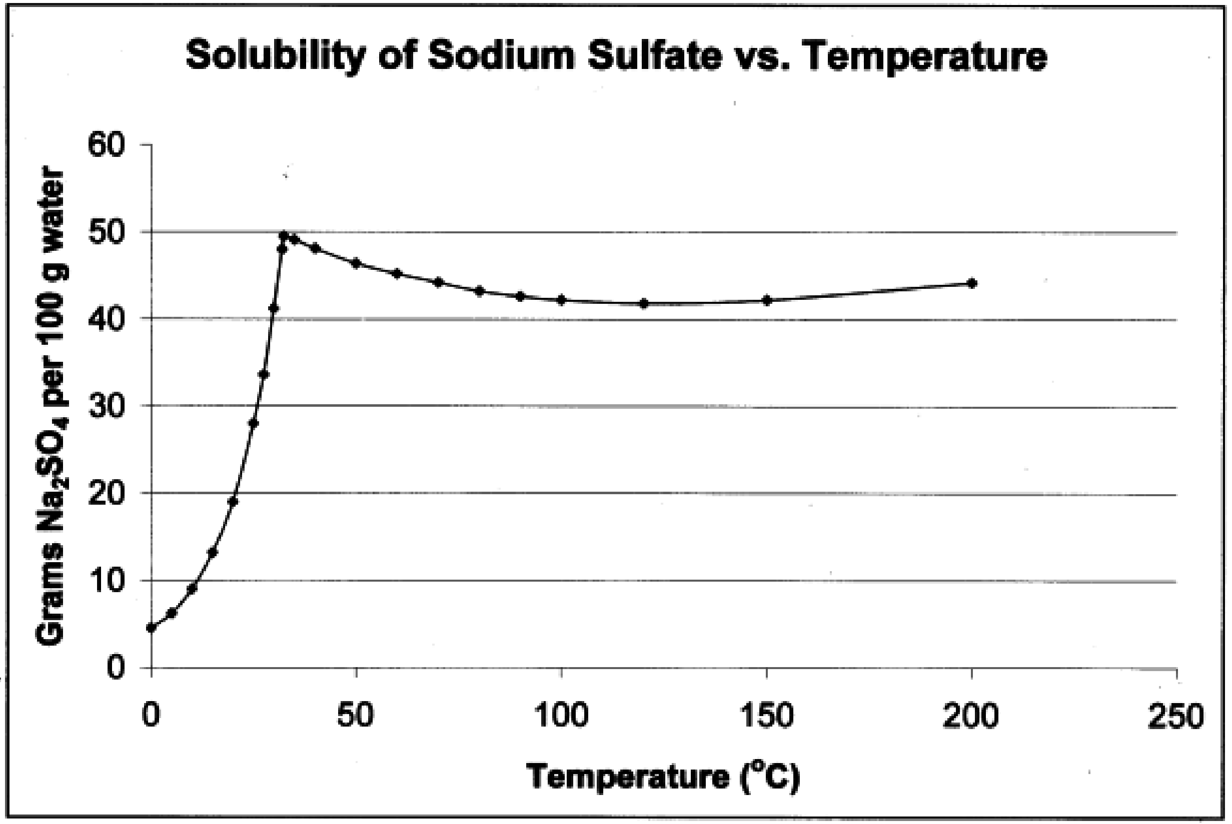
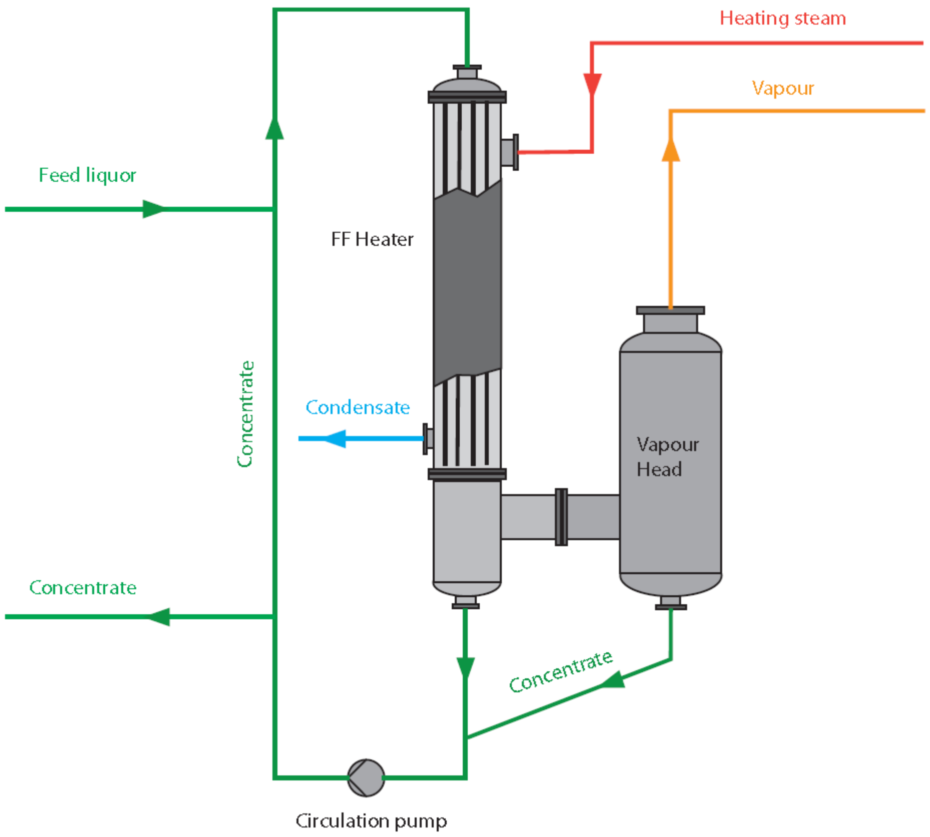
Solubility Diagrams

Solubility of sodium sulfate in water



EQUIPMENT

Falling Film Evaporator:

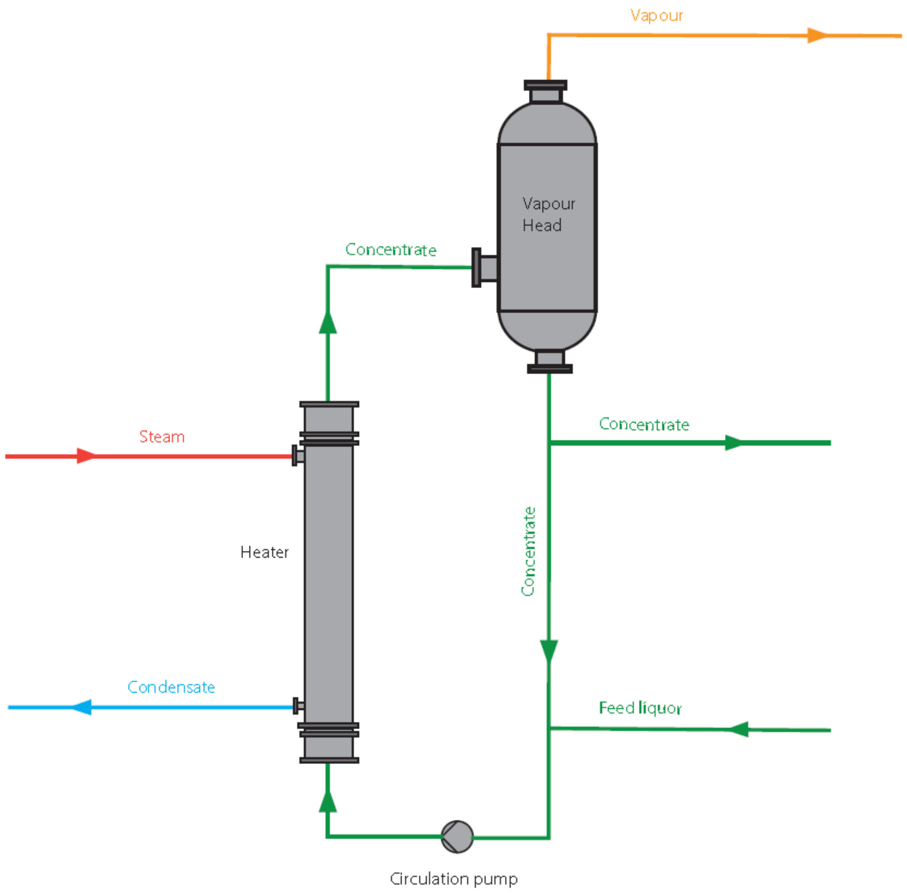


Liquid flows downwards by gravity along the inner surface of vertical tubes.

A short residence time of liquid on the heating surface and the ability to use a low temperature difference make Falling Film Evaporators suitable for heat sensitive liquids.

These evaporators can be operated between 0 and 100% of the design capacity while still maintaining good plant stability.

Forced Circulation Evaporator / Crystallizer:



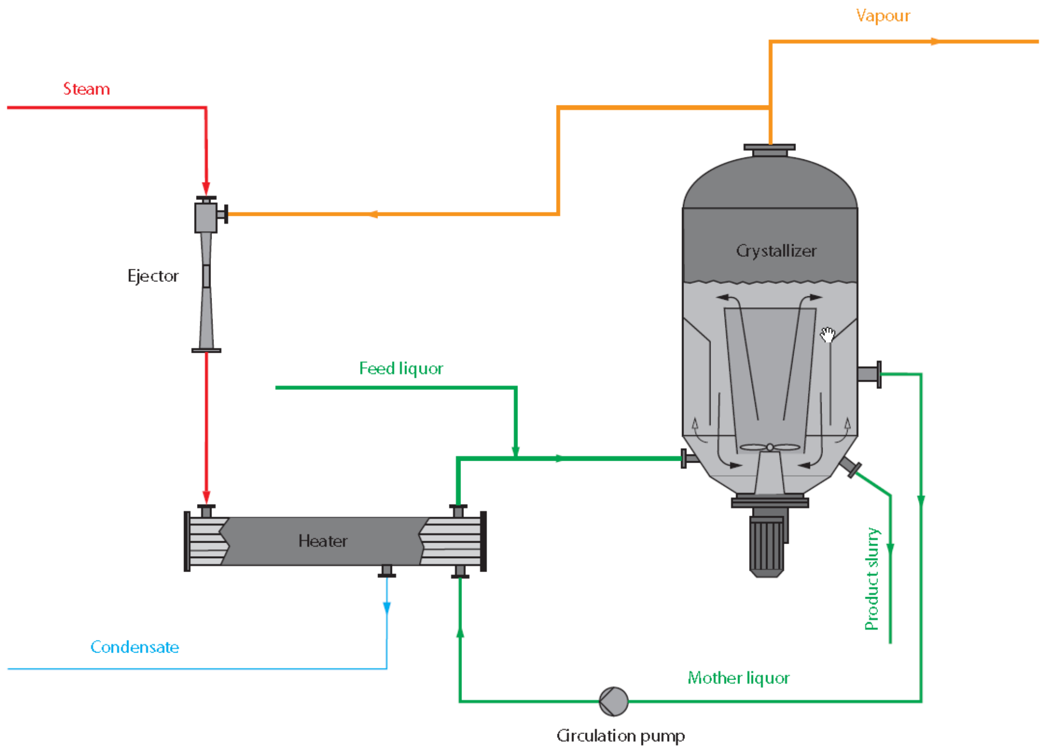
The solution is circulated by a circulation pump through the heat exchanger tubes with high velocity.

The vaporization takes place in the vapor head, where the vapor and liquor are separated by gravity and / or by centrifugal force.

Forced Circulation Evaporators are suitable for liquids containing solids and for crystallization processes.

Crystallization occurs during evaporation. This type of crystallizer suits a wide range of salts that are crystallized by evaporation but has limited capability to control crystal size.

Draft Tube Baffle (DTB) Crystallizer:

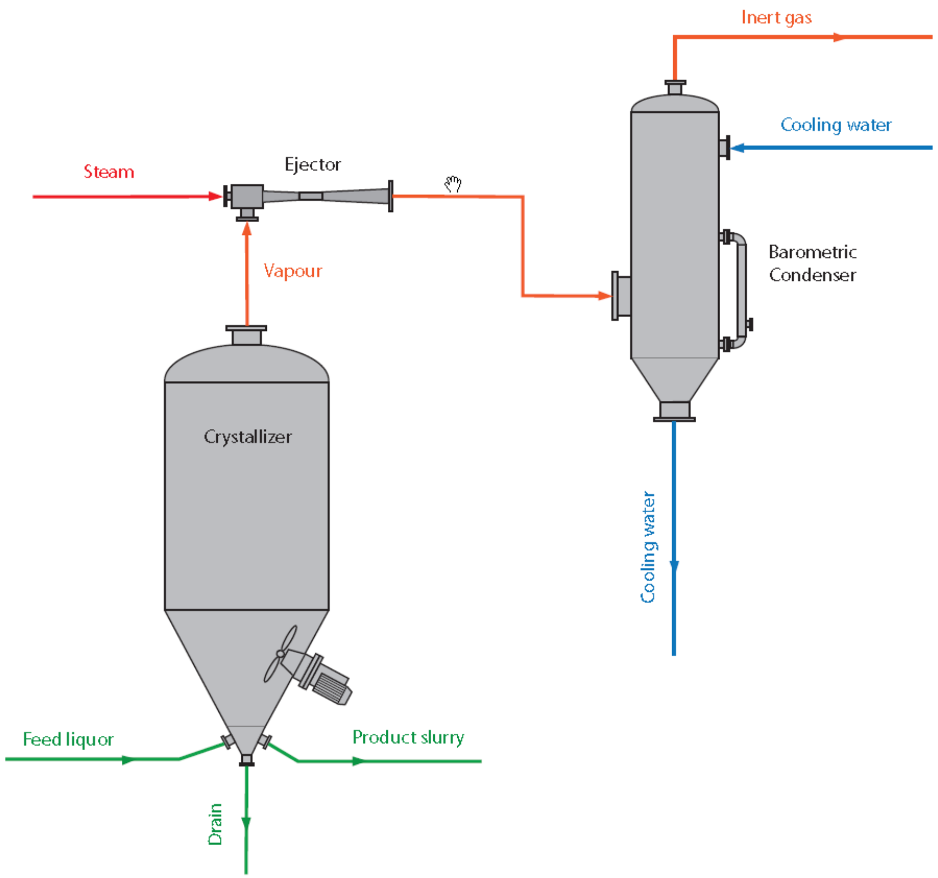


The crystals are separated from the liquid in the baffle area before the liquid is heated in the heat exchanger.

This configuration results in heating circulation relatively free of crystals; only very small crystals and nuclei will follow the mother liquor to the heat exchanger, and these are dissolved during heating.

By removing fine crystals from the liquid, the Draft Tube Baffle Crystallizer allows control of crystal growth to achieve desired crystal sizes and a narrow crystal size distribution.

Evaporative Cooling Crystallizer:



Cooling is achieved by lowering the pressure, which causes flashing.

The crystallization vessel can be either a simple agitated tank or a draft tube vessel that can be operated as a batch or continuous process.

Evaporative cooling crystallizers can be used for liquids having strong scaling or fouling potential because there are no heat exchange surfaces.

Surface Cooling Crystallizer:

Cooling is achieved either in a separate heat exchanger or with cooling coils in a vessel. Surface Cooling Crystallizers can be operated as a batch or continuous process, but the former is preferred due to fouling on cooling surfaces.

Forced Circulation Crystallizer with salt leg:

Crystals are fluidized and washed in the leg with a portion of the feed liquor which enters the bottom cone. Smaller crystals are washed back into the vapor body for additional growth and larger crystals are discharged near the bottom of the leg.

Vapor Recompression Techniques:

Primary energy consumption can be reduced by compressing vapors either mechanically by blowers or thermally by steam.

The compressed vapor is reused as a heating media for further evaporation.

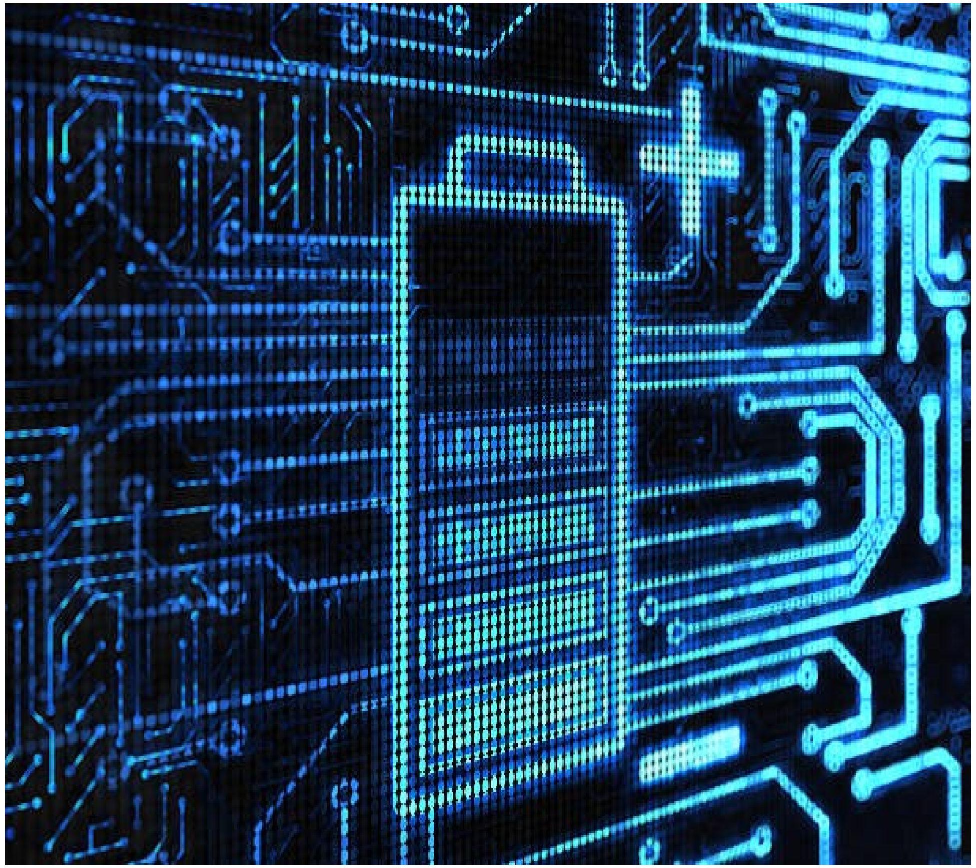
Vapor recompression can be incorporated with falling film or forced circulation evaporators.

CONCLUSION

KBR's Value Proposition

Proprietary processes to produce high-purity lithium carbonate and lithium hydroxide monohydrate

- IP-protected, continuously operated processes with long operating cycles and limited fouling
- Controlled crystallization at low supersaturation limiting secondary nucleation and promoting crystal growth
- High lithium recovery from purge streams and mother liquors of the carbonation and causticization processes
- Zero and minimum liquid discharge (ZLD) to reduce wastewater and produce clean process condensate suitable for reuse
- Reduced energy consumption by integrated multiple-effect evaporation and vapor compression systems (MVR, TVR)
- Performance guarantees based on highly sophisticated simulation tools, validated by in-house laboratory testing



Technology Differentiators

Sustainability

- Long plant lifetime
- Reduction of emissions
- Reduction of wastewater
- **Reduction of utility consumption**
- High-quality process condensate

Profitability

- Reliable production
- Continuous operation
- **Reduced plant complexity**
- High lithium yields
- Careful material selection

KBR EDGE℠

- **Proprietary processes**
- Global footprint
- On-time delivery
- **Design subject matter experts**
- **Laboratory testing facilities**

KBR's Commitment to Lithium

KBR Signs Agreement with ISU Chemical for Next Generation Battery Technology (April 19, 2023)

KBR and GeoLith Enter into an Exclusive Alliance to Offer Advanced, Zero-Emission Lithium Technology Globally (April 15, 2024)

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Summary

1

The global lithium demand is rising significantly due to the growing market for **electric vehicles**

2

Low impurity rates in the Lithium salts are critical to battery performance, reliability and safety

3

Lithium extraction requires multiple refining steps and precise process knowledge to **prevent** material losses and **minimize** the environmental impact

4

KBR has developed **fully integrated** lithium refining processes to establish high recovery rates at low operating costs

5

KBR's **proprietary** processes enable our clients to recover high-purity by-products, such as sodium sulfate

6

Challenging China's dominance will drive **further development** in the conversion and refining of lithium concentrates and intermediates

Contact us:

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