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DESIGN OF CRYSTALLISATION PLANTS FOR THE PRODUCTION OF BATTERY GRADE LITHIUM PRODUCTS

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Design Aims and Approach

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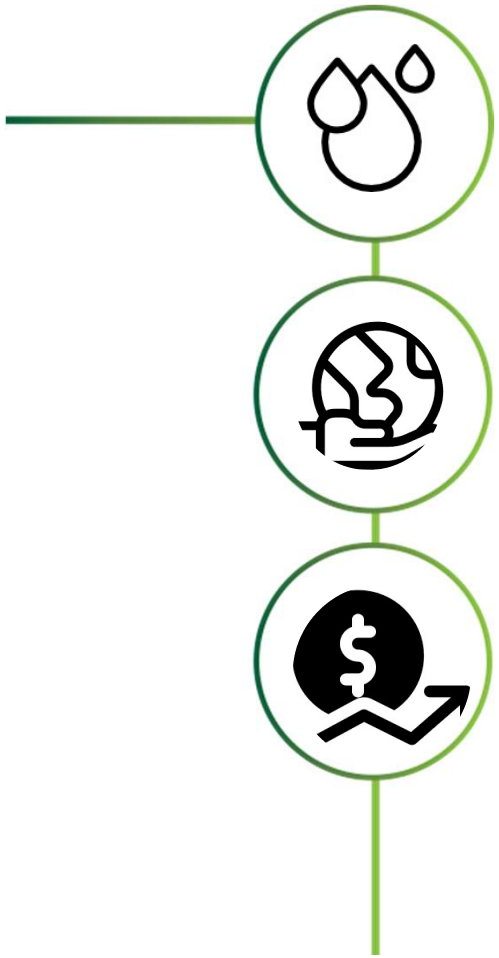

- PURITY - Free from impurities
- SUSTAINABILITY - Low carbon footprint
- VALUE - High ratio of performance / cost

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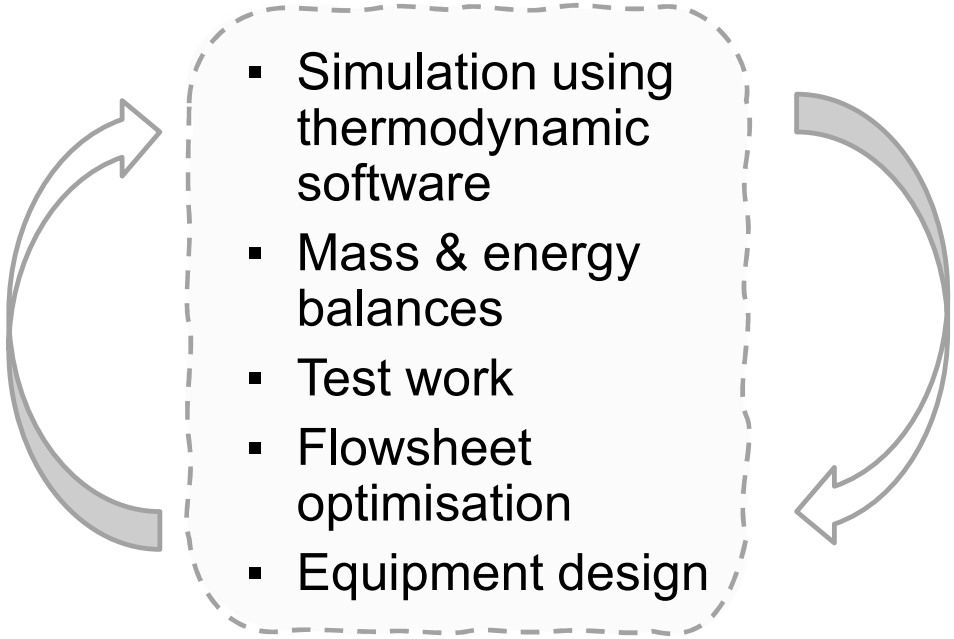
Design Approach

- Maximise purity
- Maximise yield
- Minimise CAPEX and OPEX costs
- Ease of operation with robust design



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Evaporator / Crystalliser Fundamentals

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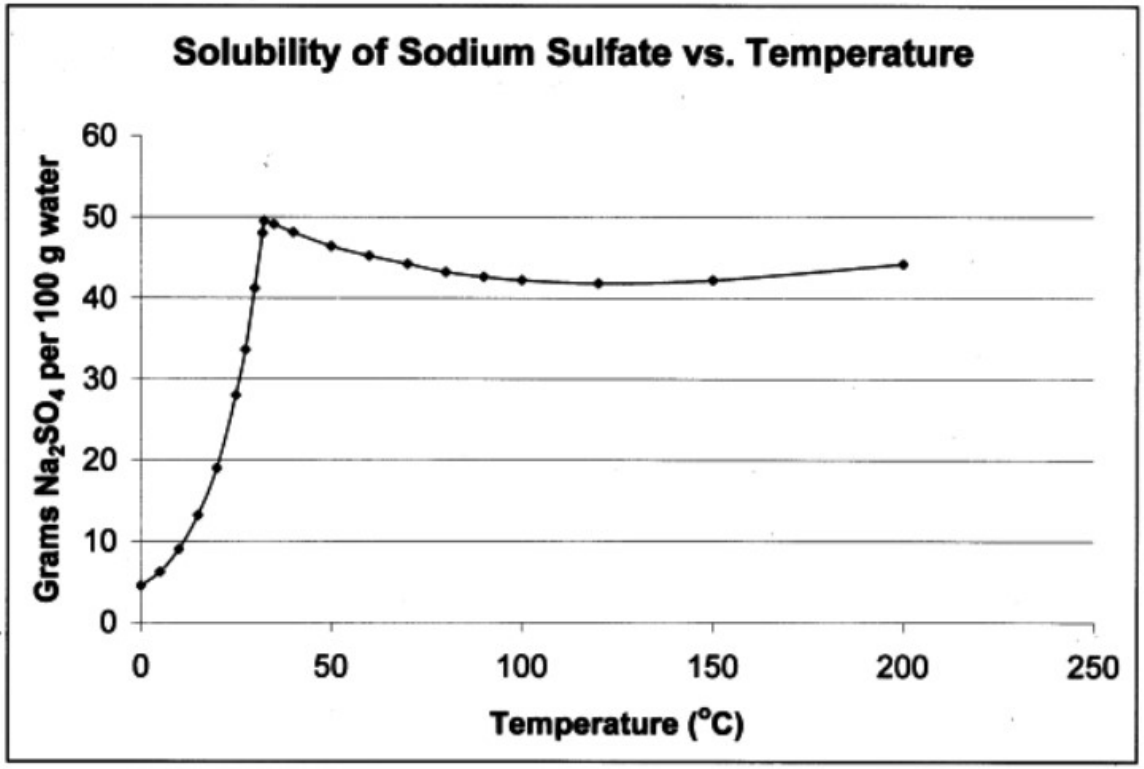
EVAPORATION

- Produces a concentrate for discharge or further treatment
- Recovers clean water
- Handles tough liquors that biological and membrane treatment cannot handle

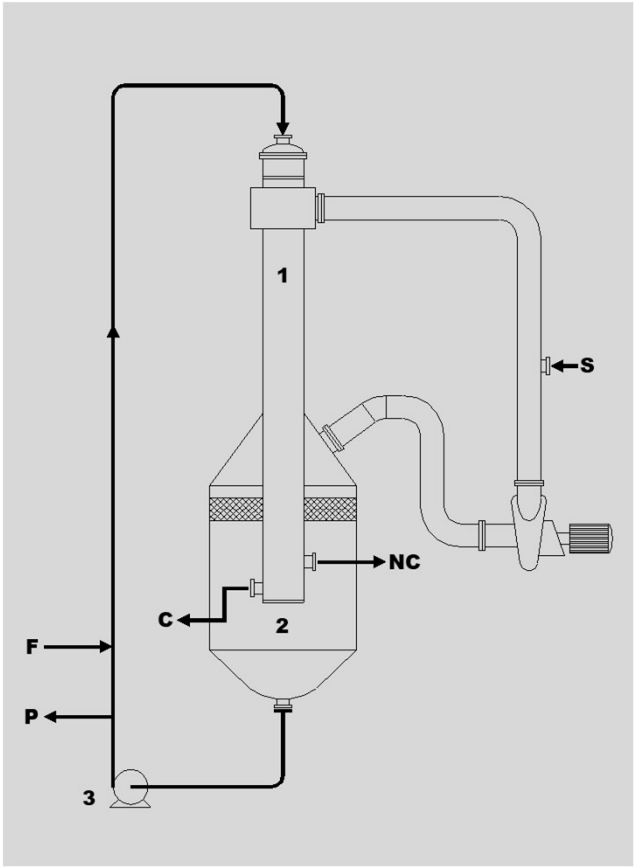
CRYSTALLISATION

- Thermal: Recovers clean water and solid waste or a usable product.
- Cooling crystallisation: recovery of a specific component
- Purification steps

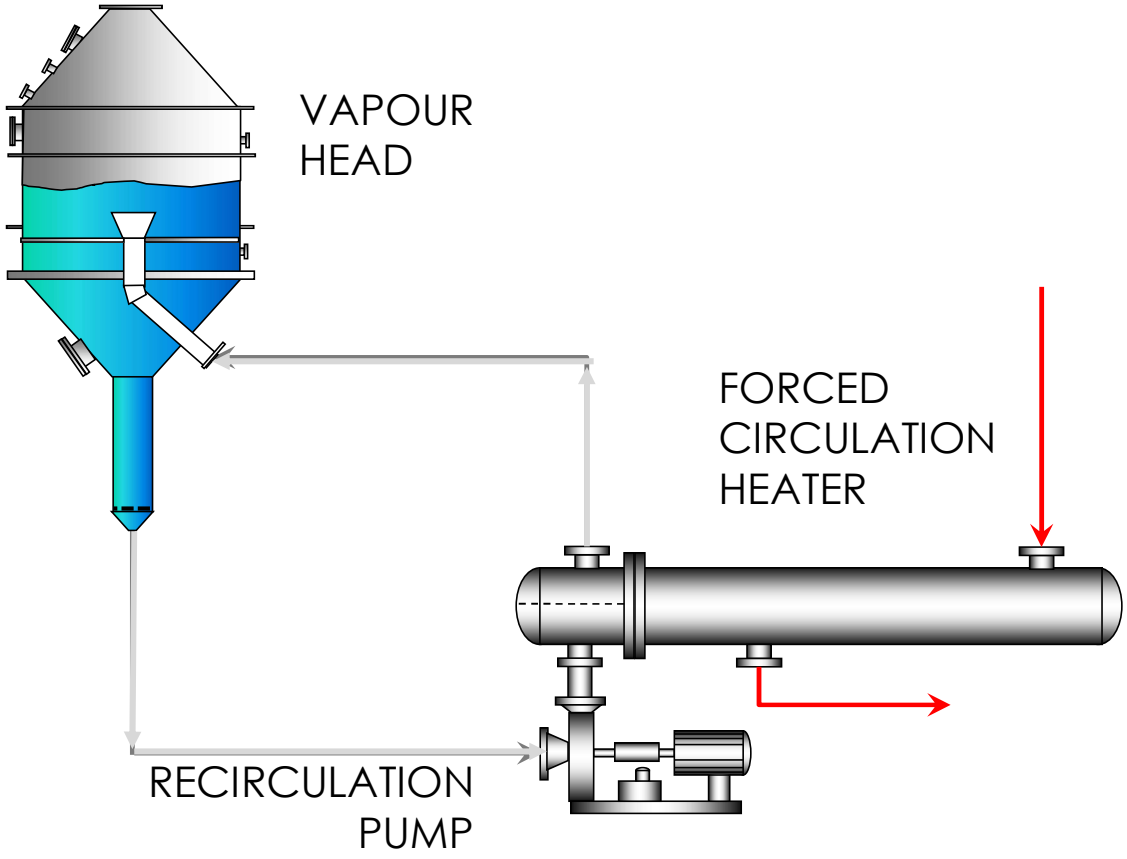

Solubility of Sodium Sulfate vs. Temperature
Grams Na_2SO_4 per 100 g water
60
50
40
30
20
10
0
0
50
100
150
200
250
Temperature (°C)

FALLING FILM EVAPORATOR

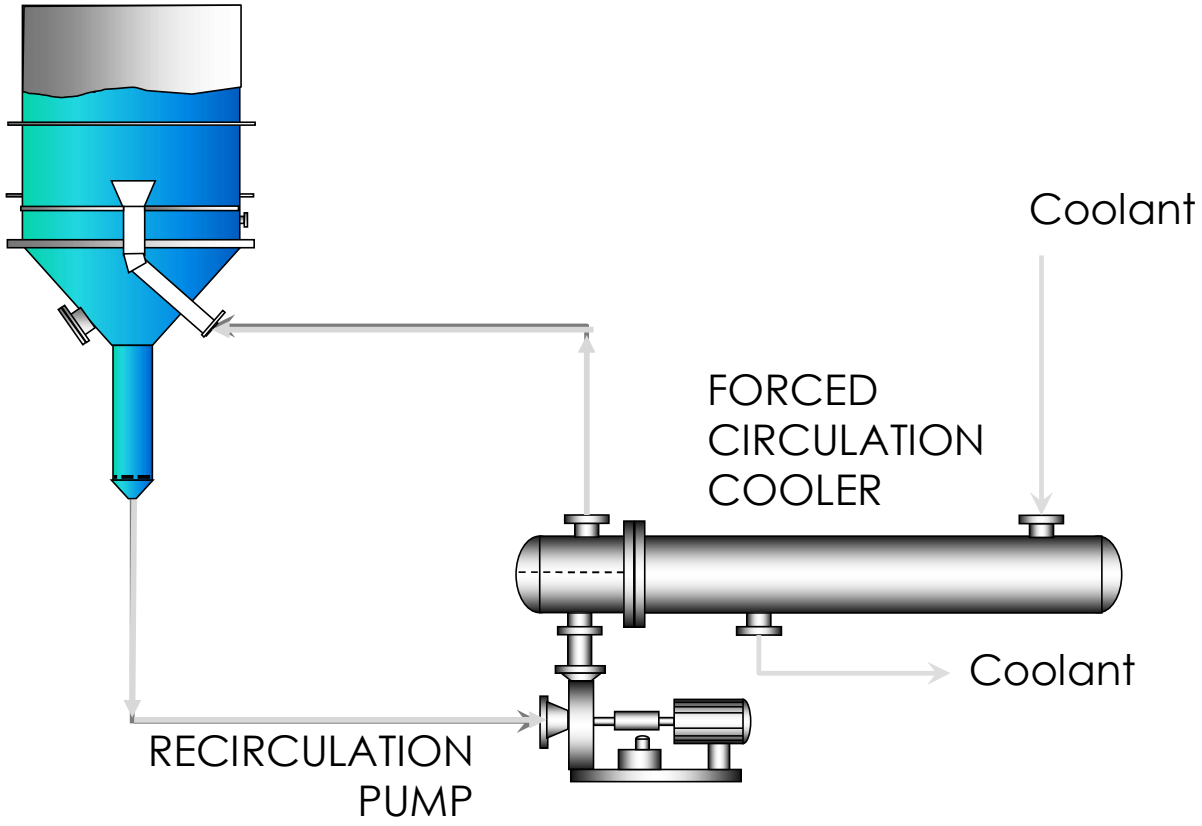
- Liquor re-circulated to top of heat exchanger
- Liquor heated as it falls as a film on inside of tube
- High heat transfer rates
- Low space requirements
- High turndown capability
- Not suitable for crystals or scaling liquors



FORCED CIRCULATION- THERMAL



FORCED CIRCULATION- COOLING



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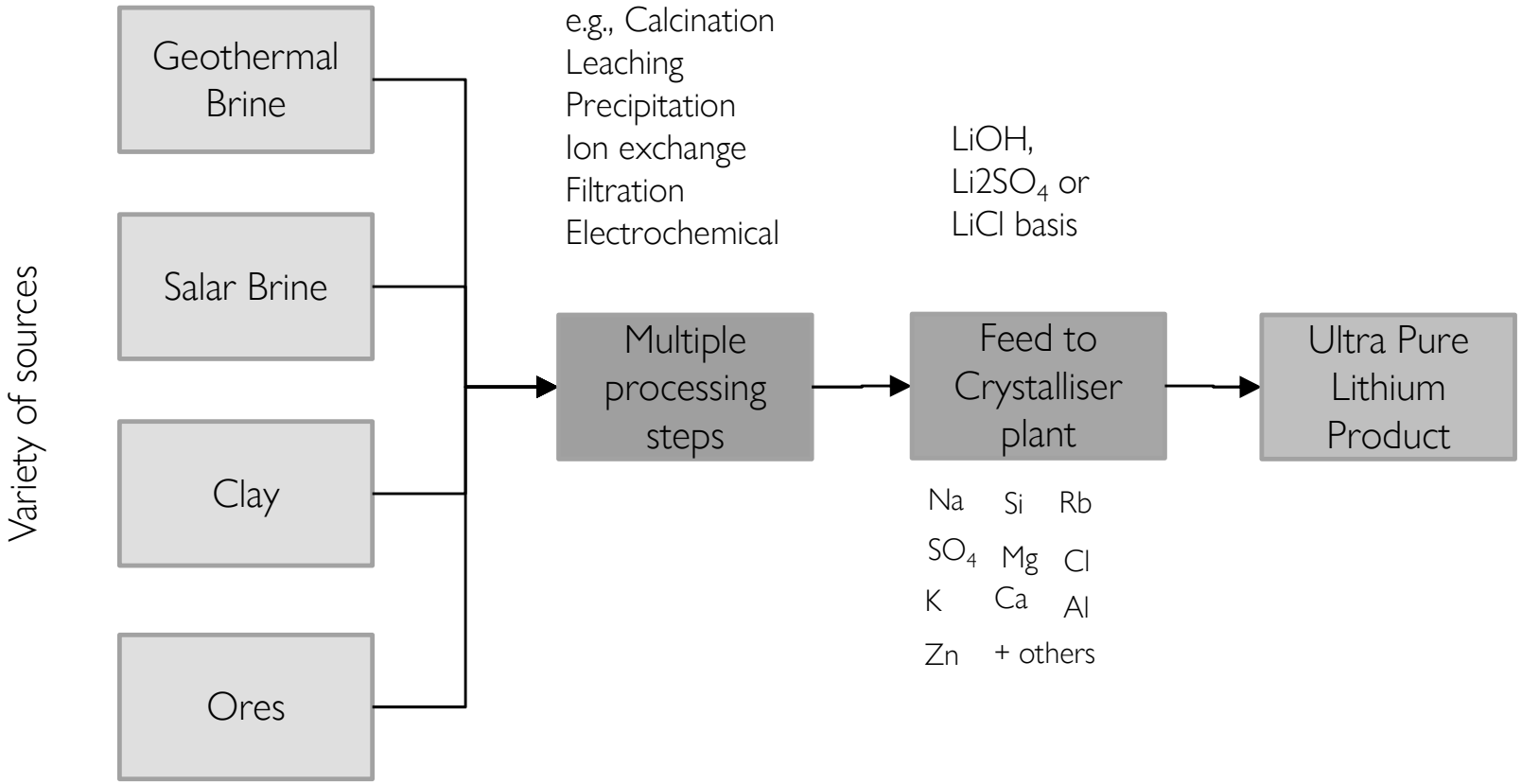
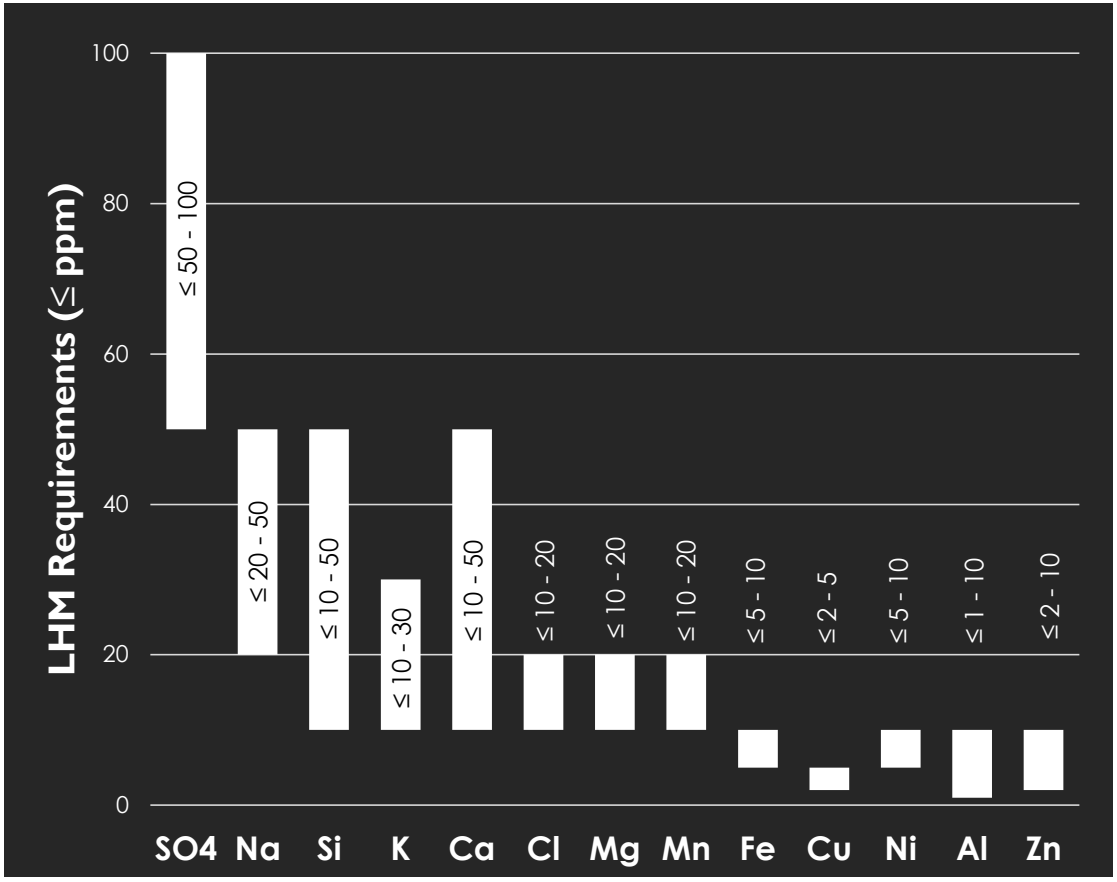
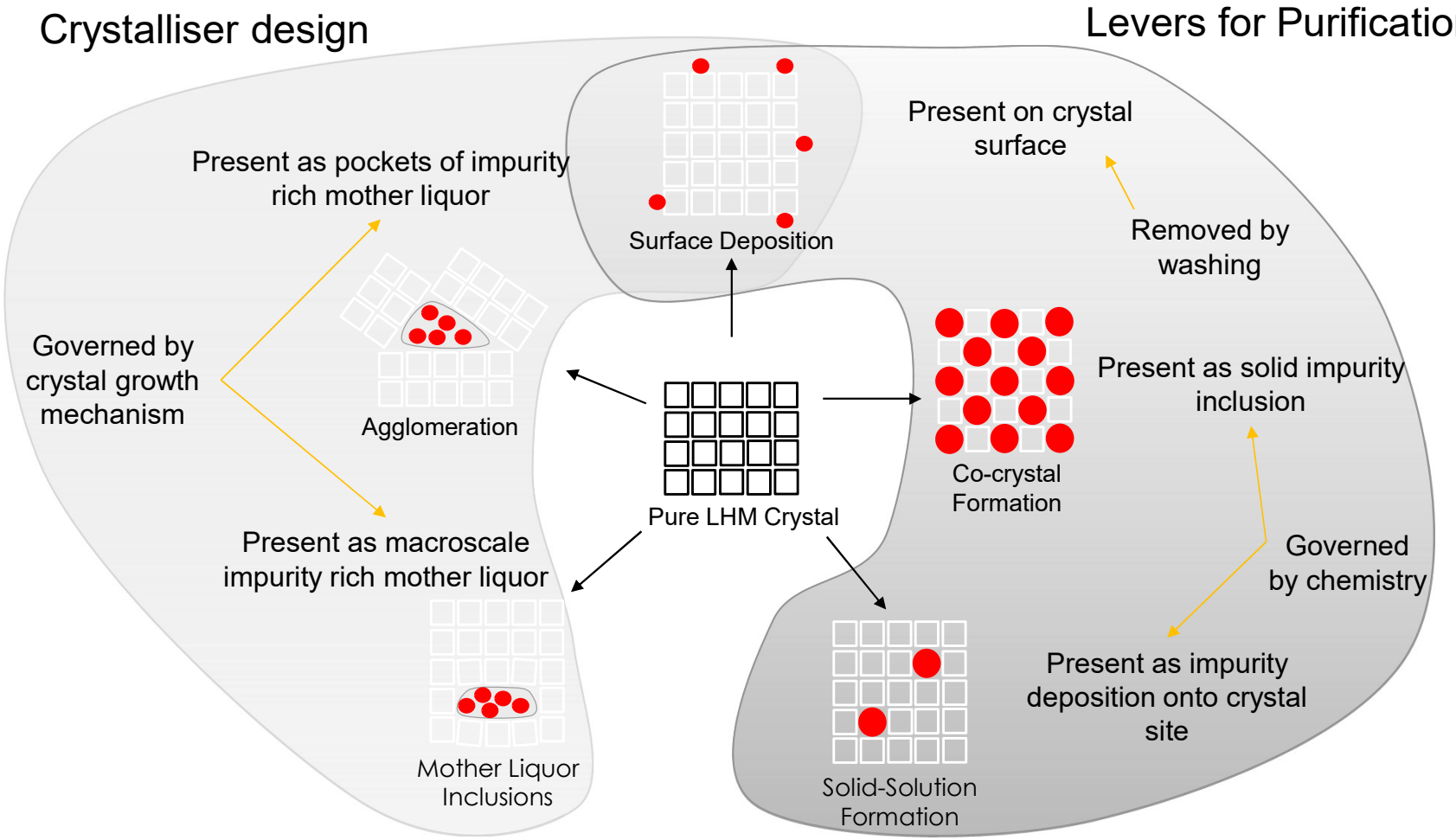
Purity


Variety of sources
Geothermal Brine
Salar Brine
Clay
Ores
e.g., Calcination
Leaching
Precipitation
Ion exchange
Filtration
Electrochemical
Multiple processing steps
LiOH,
Li2SO4 or
LiCl basis
Feed to Crystalliser plant
Na Si Rb
SO4 Mg Cl
K Ca Al
Zn + others
Ultra Pure Lithium Product



- Very low concentrations.
- Up to 3 nines LHM required (99.9% excl. CO_3).
- Future LHM purity may require as high as 4 nines (99.99% at < 100 total ppm impurities excl. CO_3).


Crystalliser design
Levers for Purification
Present as pockets of impurity rich mother liquor
Governed by crystal growth mechanism
Agglomeration
Present as macroscale impurity rich mother liquor
Mother Liquor Inclusions
Surface Deposition
Present on crystal surface
Removed by washing
Pure LHM Crystal
Co-crystal Formation
Present as solid impurity inclusion
Governed by chemistry
Present as impurity deposition onto crystal site
Solid-Solution Formation

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Case Study

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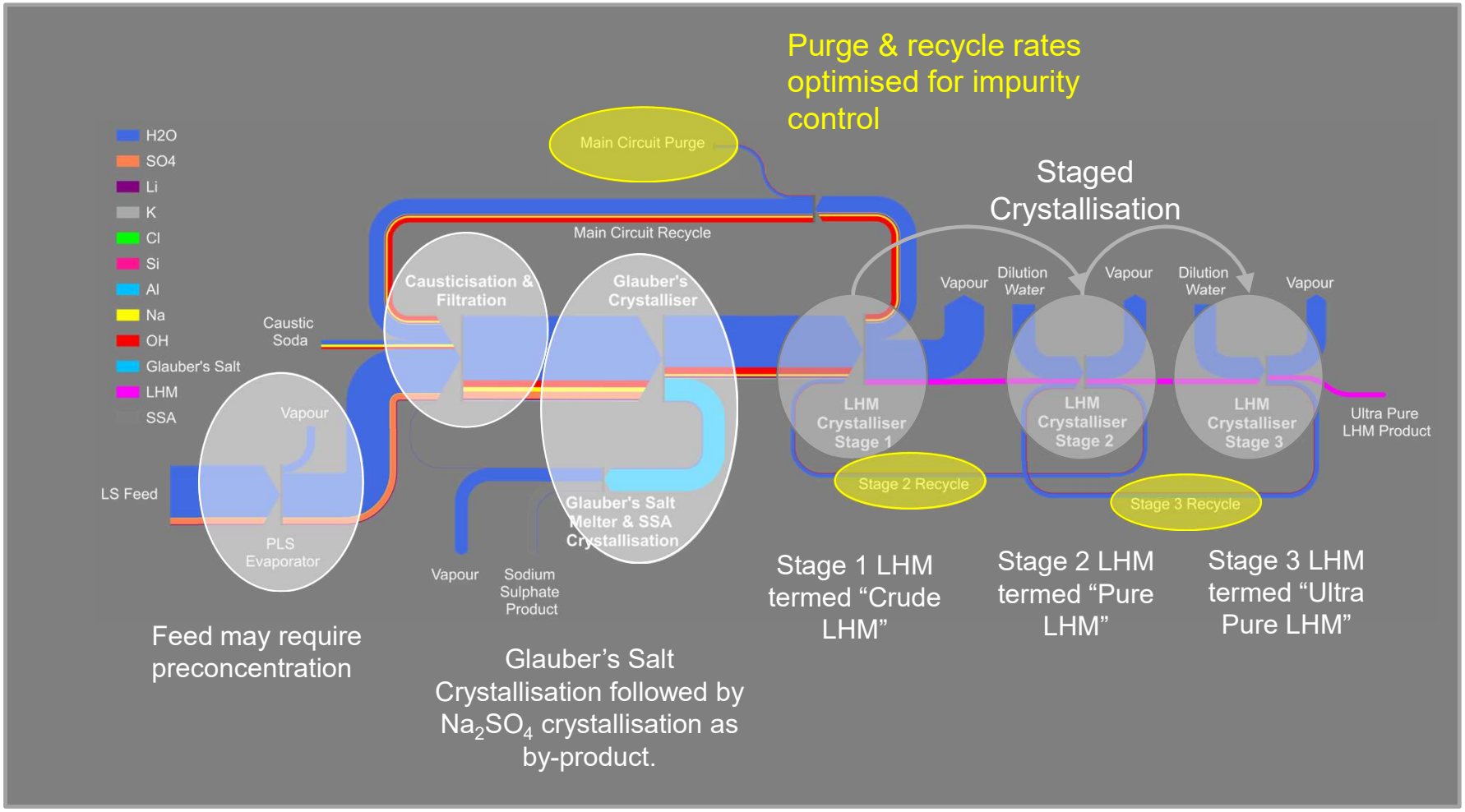
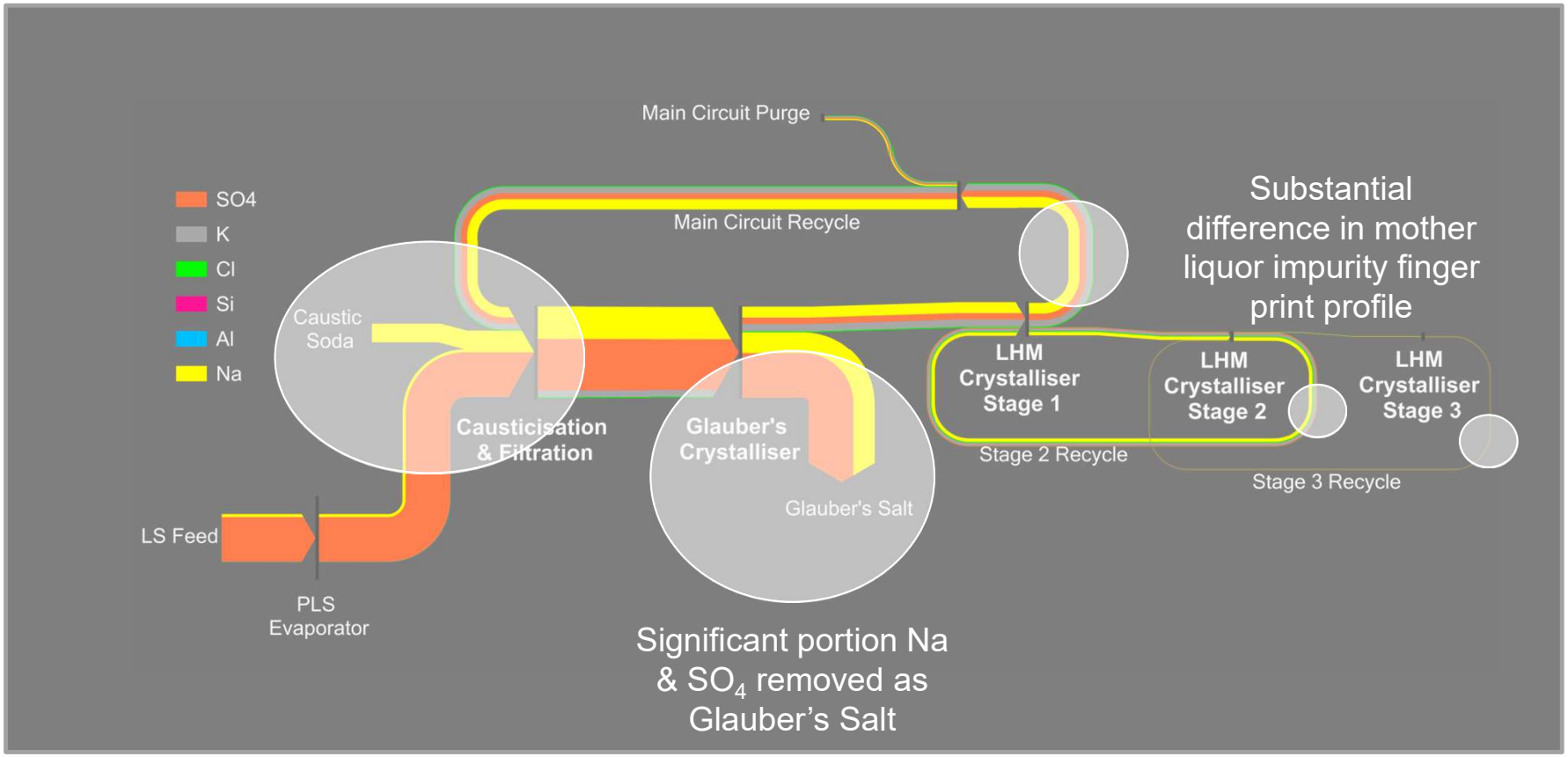
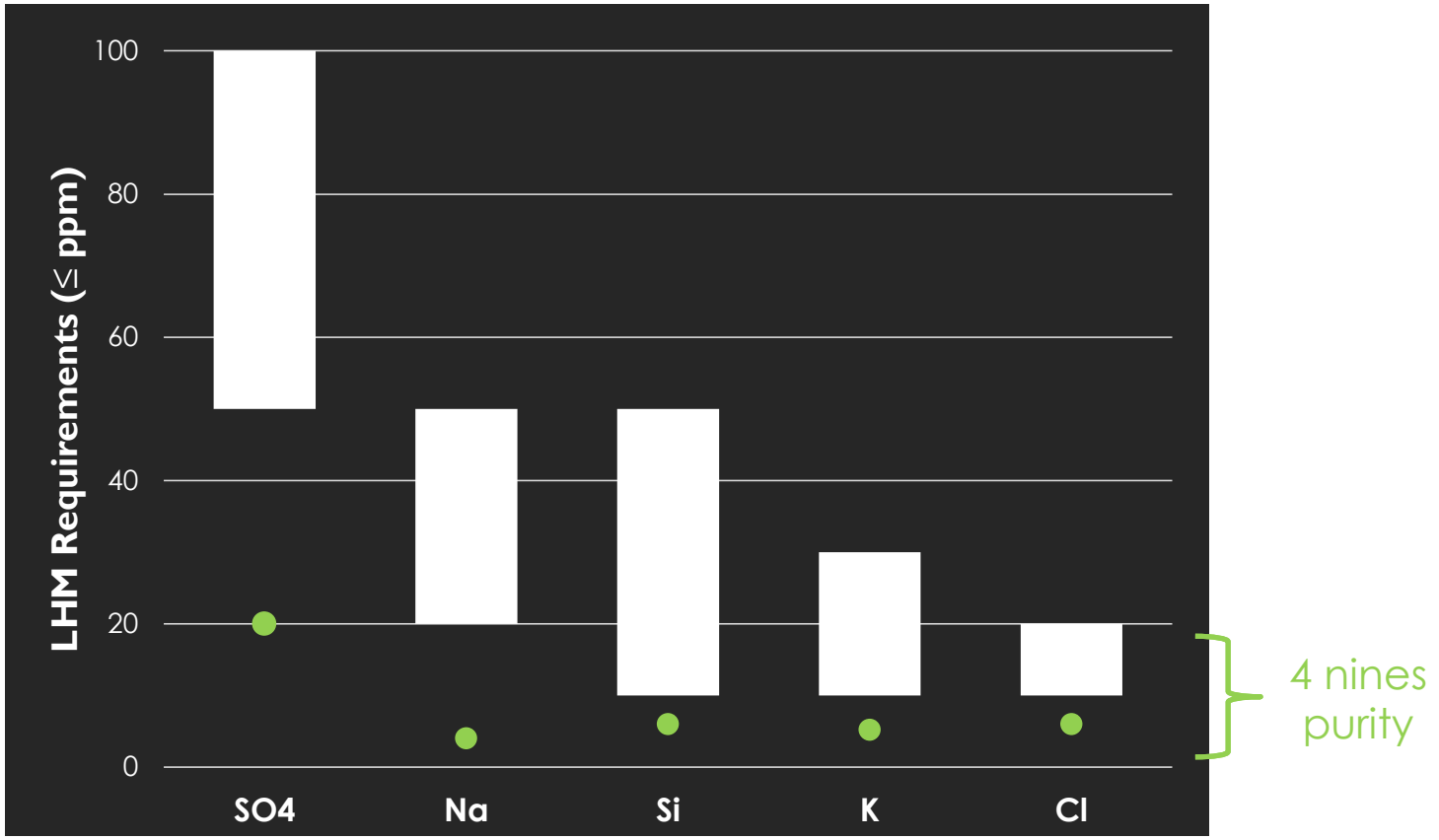
Feed basis: Lithium sulphate **PLS** generated from traditional β-Spodumene sulphation route.

Range of main impurities presented in table below on a 10 g/L Li basis:

Component	Unit	Typical	Good	Excellent
Na	g/L	6-8	6	5
SO_4	g/L	70-80		
K	g/L	0.7-0.9	0.6	0.3
Cl	mg/L	< 100	70	< 40
Si	mg/L	10-20	10	< 5
Other typical trace level impurities include Ca, Mg, Cs, Zn, Al +…				


Purge & recycle rates optimised for impurity control
H2O
SO4
Li
K
Cl
Si
Al
Na
OH
Glauber's Salt
LHM
SSA
Main Circuit Purge
Main Circuit Recycle
Staged Crystallisation
Causticisation & Filtration
Glauber's Crystalliser
Caustic Soda
Vapour
Dilution Water
Vapour
Dilution Water
Vapour
LHM Crystalliser Stage 1
LHM Crystalliser Stage 2
LHM Crystalliser Stage 3
Ultra Pure LHM Product
Stage 2 Recycle
Stage 3 Recycle
LS Feed
Vapour
PLS Evaporator
Glauber's Salt Melter & SSA Crystallisation
Vapour
Sodium Sulphate Product
Stage 1 LHM termed "Crude LHM"
Stage 2 LHM termed "Pure LHM"
Stage 3 LHM termed "Ultra Pure LHM"
Feed may require preconcentration
Glauber's Salt Crystallisation followed by Na_2SO_4 crystallisation as by-product.


Main Circuit Purge
Main Circuit Recycle
SO4
K
Cl
Si
Al
Na
Caustic Soda
Causticisation & Filtration
Glauber's Crystalliser
Glauber's Salt
LS Feed
PLS Evaporator
LHM Crystalliser Stage 1
LHM Crystalliser Stage 2
LHM Crystalliser Stage 3
Stage 2 Recycle
Stage 3 Recycle
Substantial difference in mother liquor impurity finger print profile
Significant portion Na & SO_4 removed as Glauber's Salt


LHM Requirements (≤ ppm)
100
80
60
40
20
0
SO4
Na
Si
K
Cl
4 nines
purity

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Conclusions

CONCLUSIONS

- The requirements for LHM product purity are becoming ever more stringent.
- Well defined empirical impurity entrainment models along with test work validation helps us develop a robust flow sheet that can meet the desired product purities.
- JordProxa has expertise in the design of the flowsheets that can produce Ultra Pure LHM product with the current 3-nines and the future 4-nines purity from a variety of different feed compositions.

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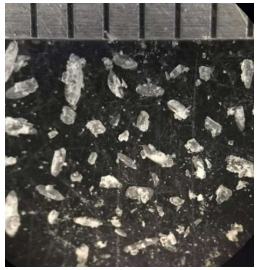
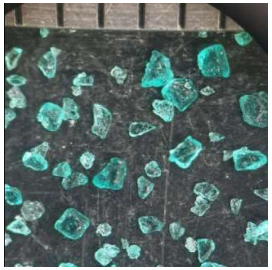
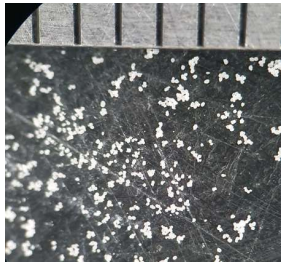
$LiOH.H_2O$	$NiSO_4.6H_2O$	$CoSO_4.7H_2O$	$MnSO_4.H_2O$
			
			

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