CMG COMPUTER MODELLING GROUP LTD.


# Lithium Production Case Study

#FutureOfSimulation

Simulation Technology for the Energy Transition

# Agenda

General Review of Lithium Exploitation

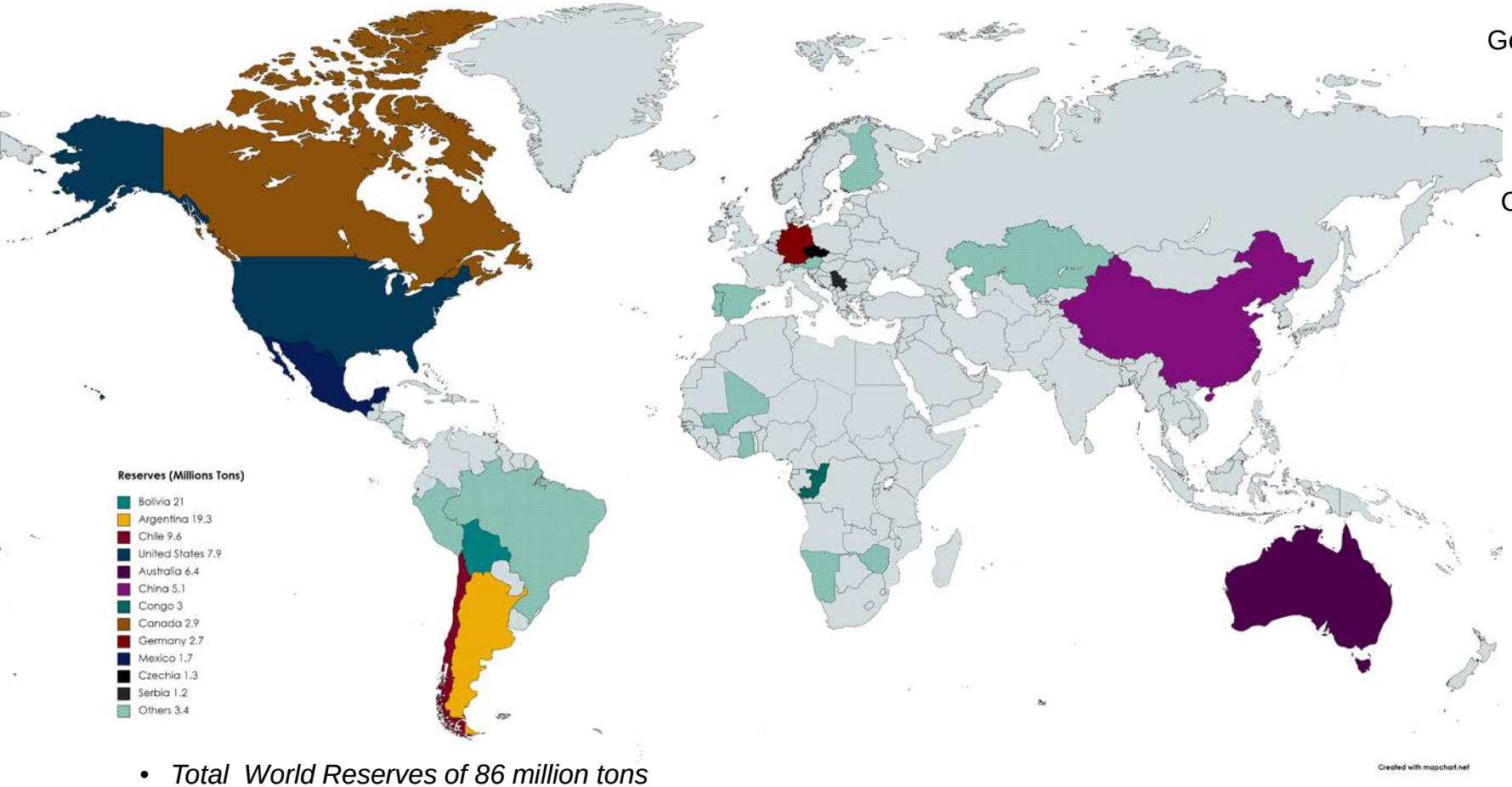
- Reserves
- Market
- Type of sources

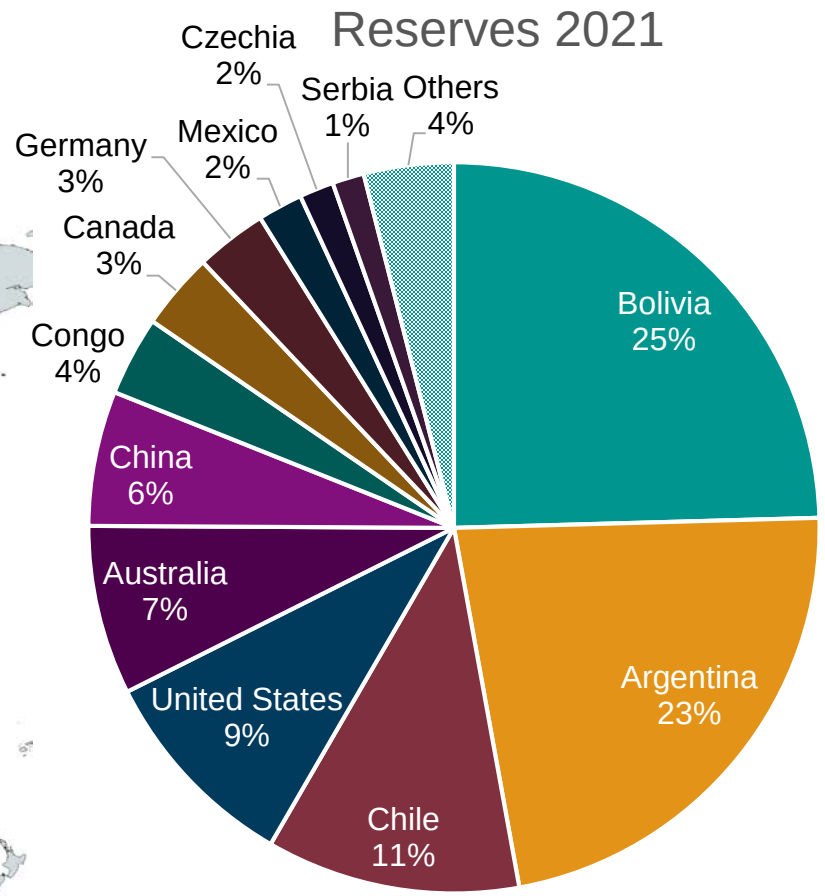
CMG Technology to Simulate Lithium Production

- GEM/STARS
- CMOST


# General Review of Lithium Exploitation

# Worldwide Lithium Reserves




- *Total World Reserves of 86 million tons*
- *Others: Peru, Mali, Zimbabwe, Brazil, Spain, Portugal, Ghana, Austria, Finland, Kazakhstan, Namibia*

Source: modified from U.S. Geological Survey, Mineral Commodity Summaries, January 2021

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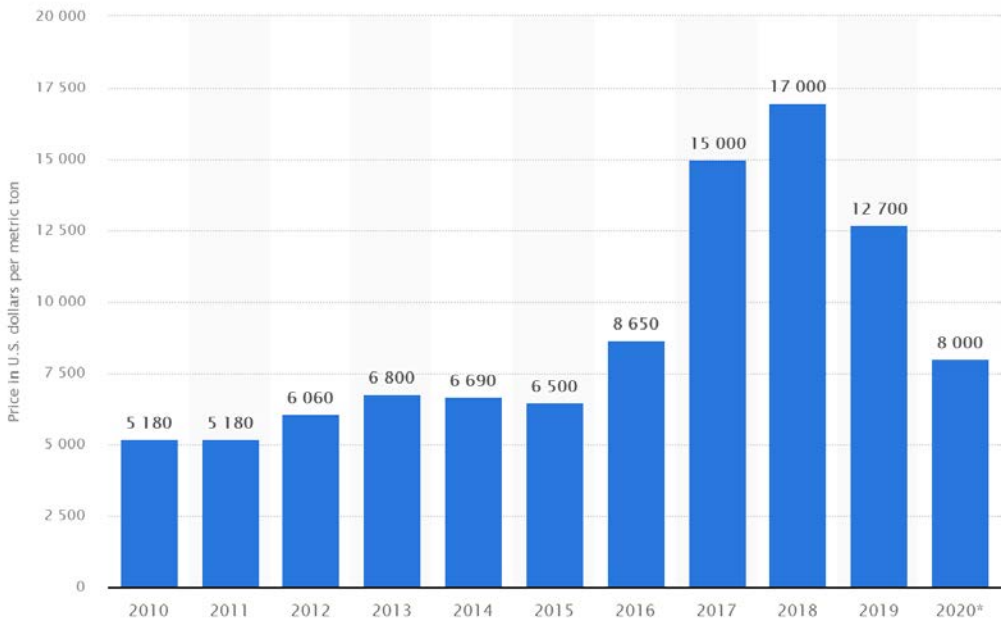
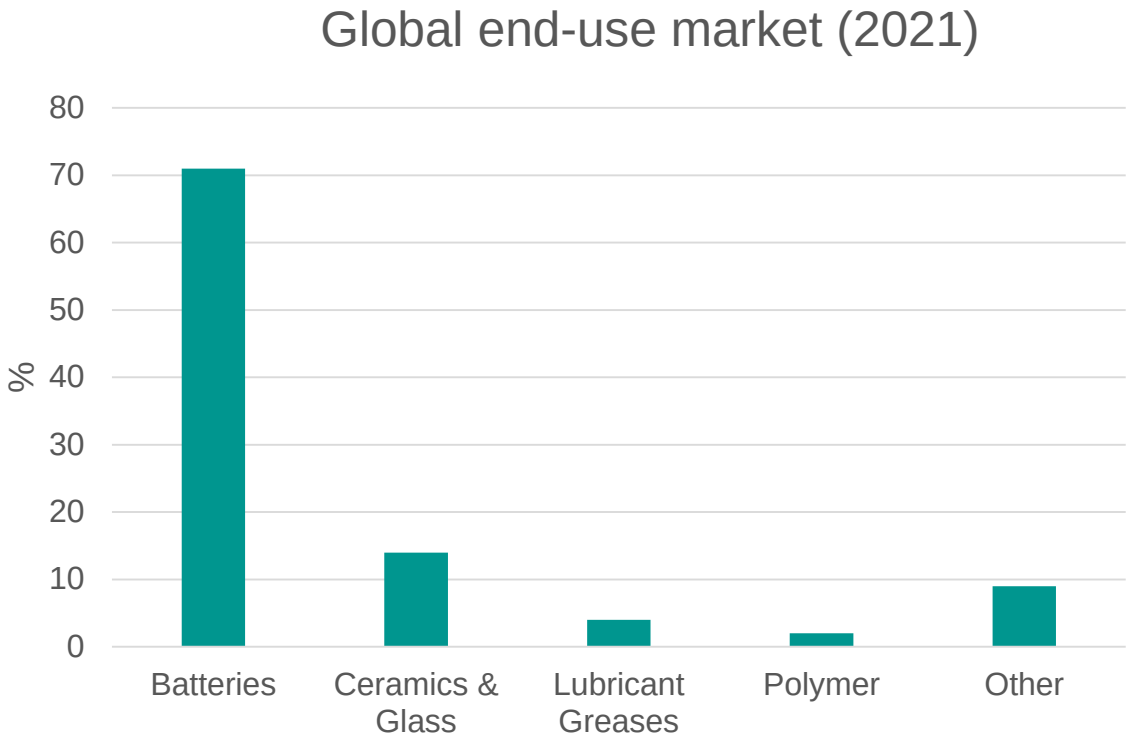
# Market




*Source: Statista*

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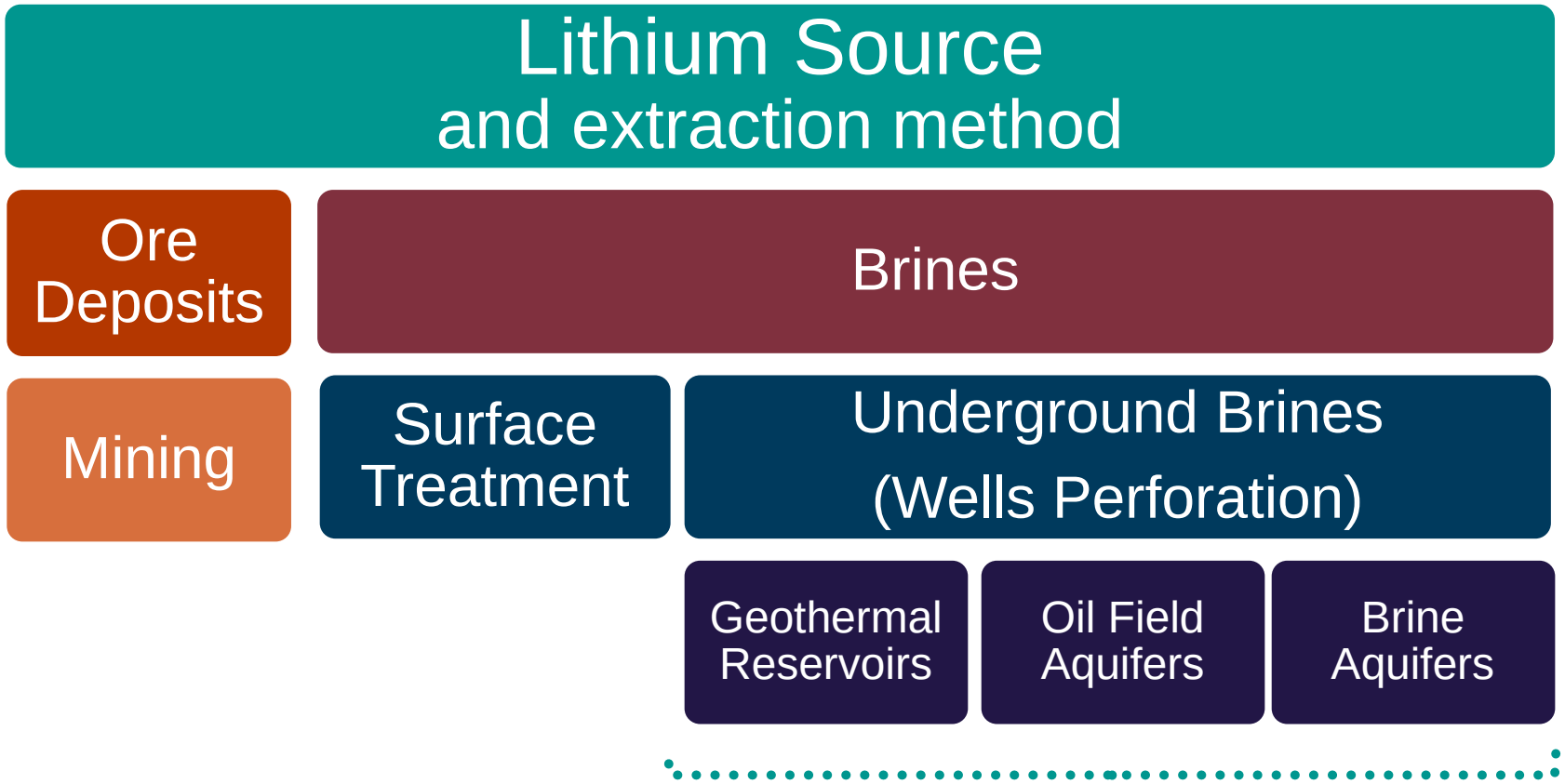
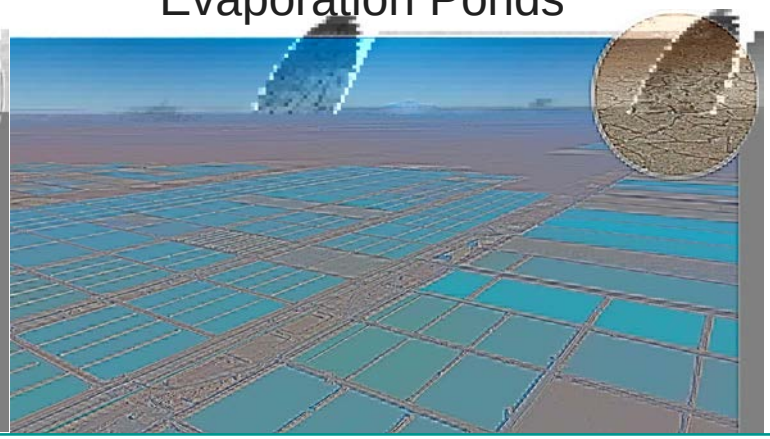
# General Review



# Lithium Recovery Techniques

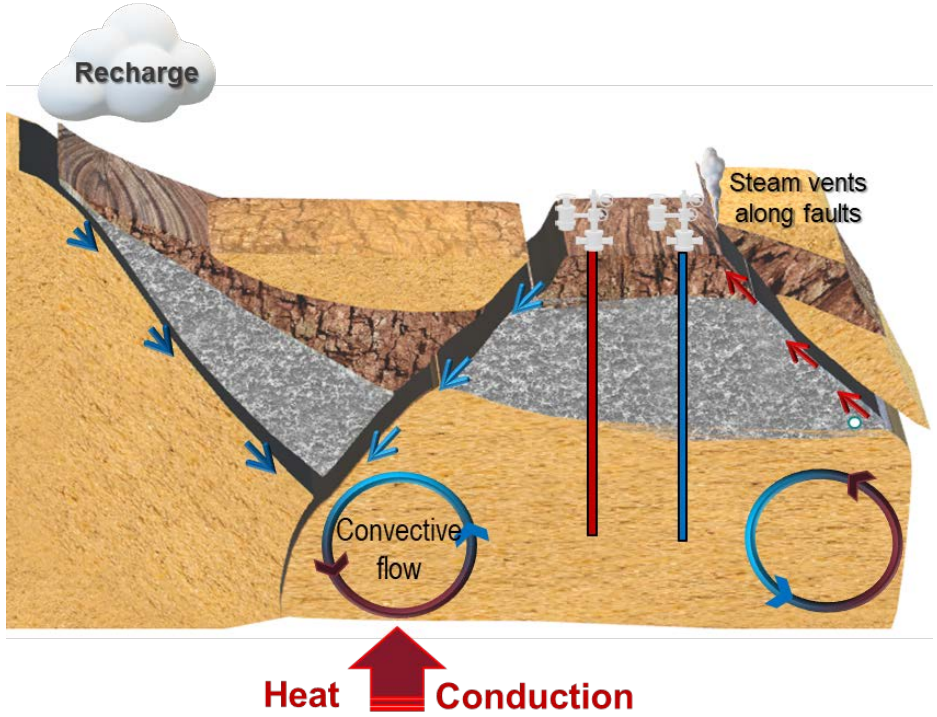

*Source: Reuters, 2019*

| | Hard Rock Mining | Evaporation Ponds | Zero Carbon Lithium |
|---|---|---|---|
| |  |  |  |
| CO2 (kg) | 15,000 | 5,000 | 0 |
| Water (m3) | 170 | 469 | 80 |
| Land (m2) | 464 | 3124 | 6 |
| Cost ($) | 6,855 | 5,872 | 3,140 |

*Source: Vulcan Energy and Minviro LCA, 2020*

# Geothermal Aquifers

Geothermal Energy & Lithium Extraction



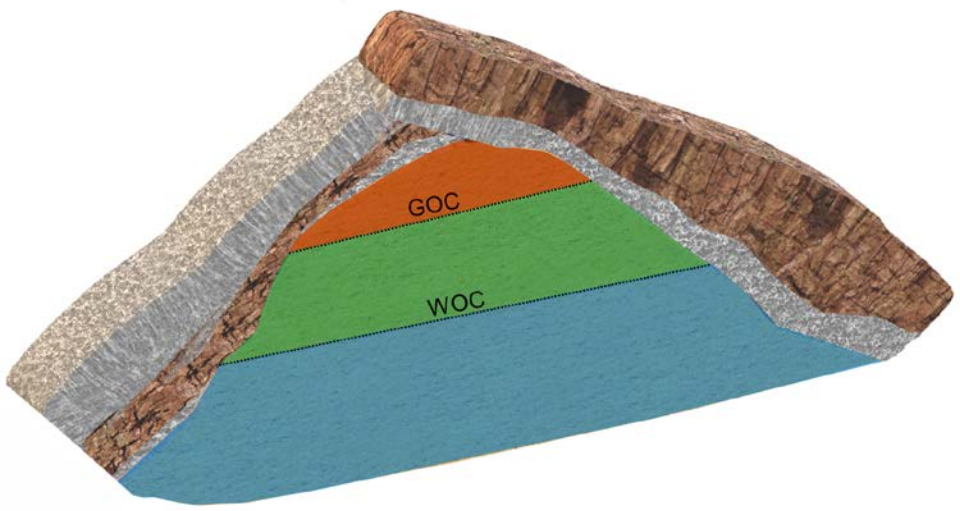

## Geothermal brine

water produced from geothermal reservoirs

- Hybrid processes for electricity and Lithium production
- Some fields have considerable Lithium associated with deep geothermal brines – can provide massive additional revenue
- Under research

- *Cerro Prieto (Mex)*
- *Salton Sea (USA)*
  *Can provide 40% of global Lithium demand (CEC)*

# Oil Field Aquifers

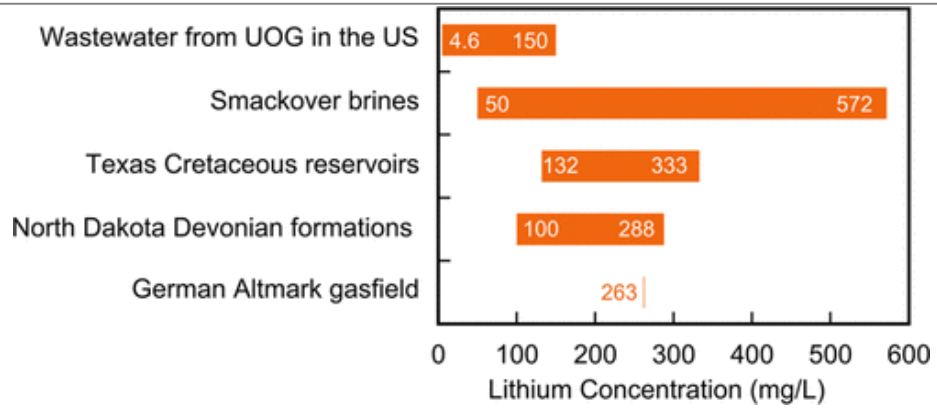



## Waste Water

### Water produced from existing fields

- Lower Lithium concentration
- No new wells needed
- Additional revenue by separating and extracting Lithium

*Over 7 Mt LCE in Leduc Formation (E3 Metals, Alberta)*

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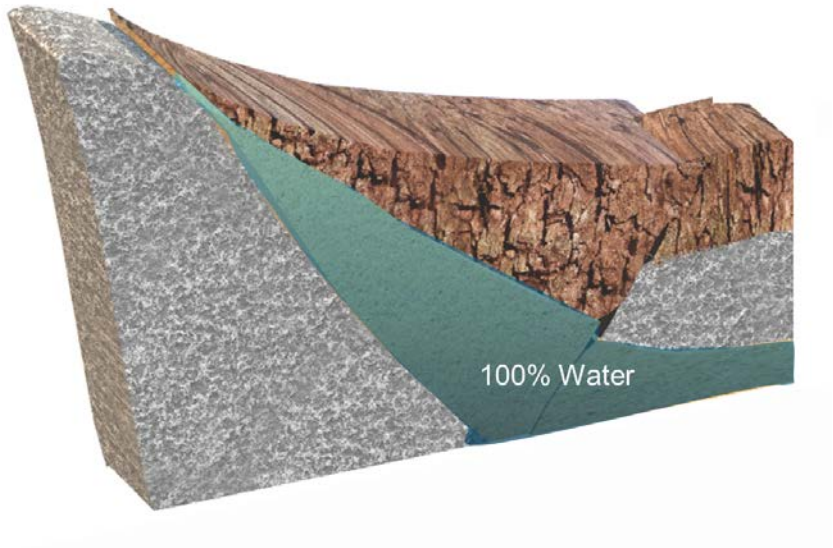
# Brine Aquifers



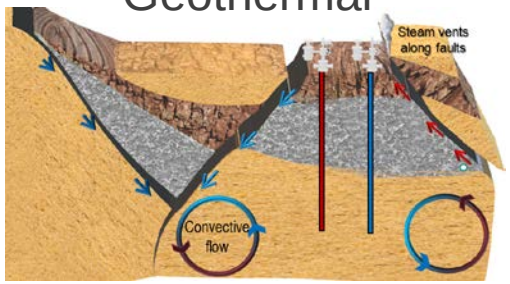

## Brine
### Water from aquifers

- Higher Lithium concentration
- Projects exclusive for Lithium extraction (no oil/gas production)

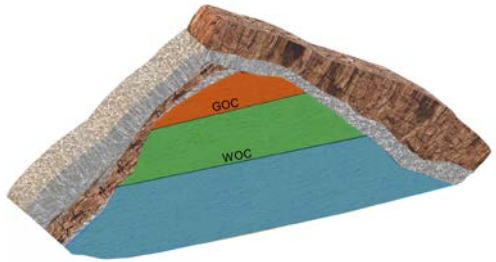
- Clayton Valley (USA)
- Uyuni (Bolivia)
- Atacama (Argentina)
- Kachi (Argentina)

# Phenomena involved

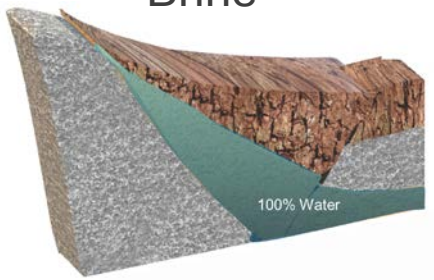
Geothermal




Oil Field




Brine




- Hydrothermal Alteration
- Thermal Support
- Reservoir Heterogeneities
- Mineral Deposition
- Porosity Reduction
- Fluid Alteration Due To Reaction With The Rock
- Complex Geology / Active Faults
- Subsidence

# Agenda

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CMG Technology to Simulate Lithium Production

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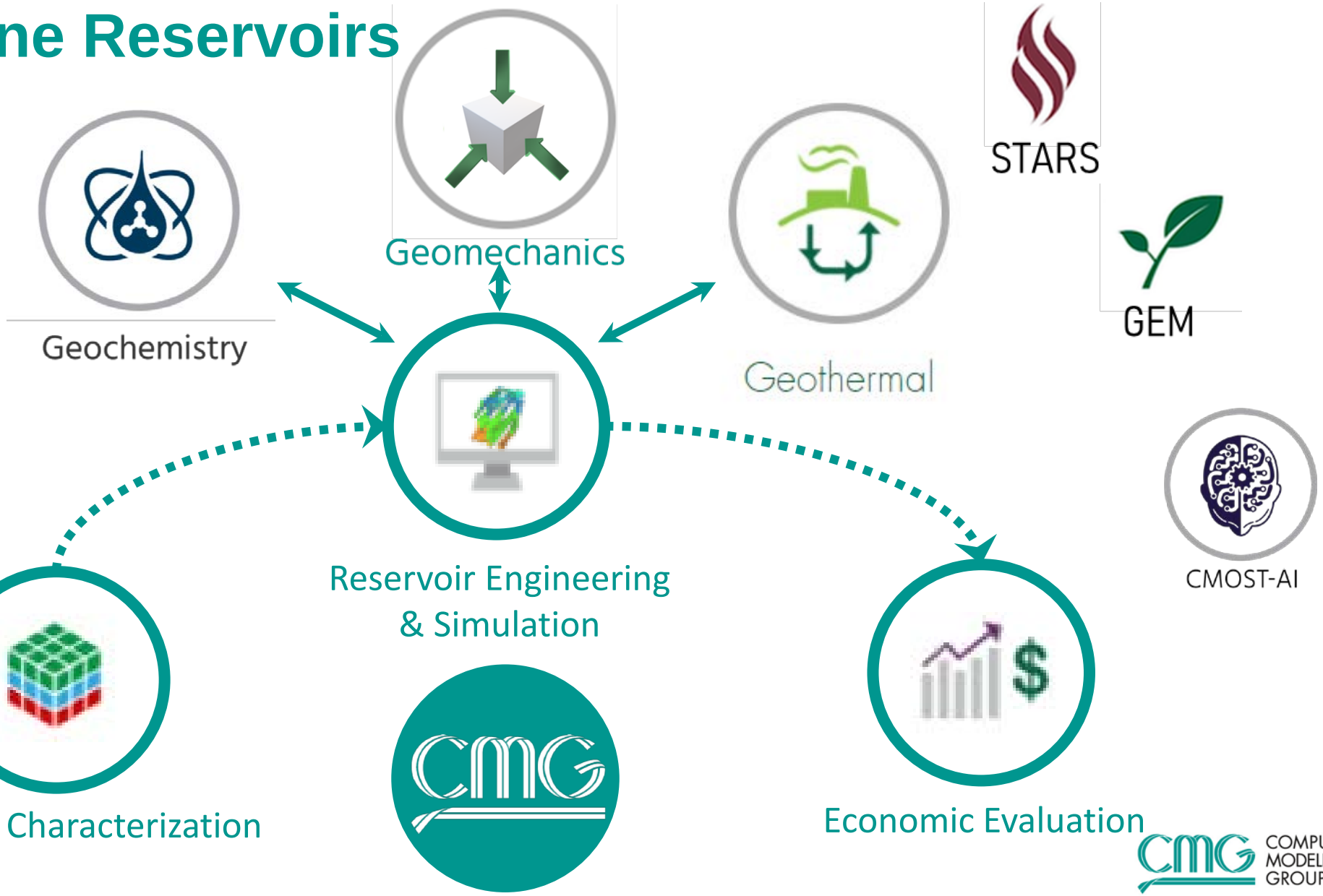
# CMG Technology to simulate Lithium production

# Lithium Brine Reservoirs

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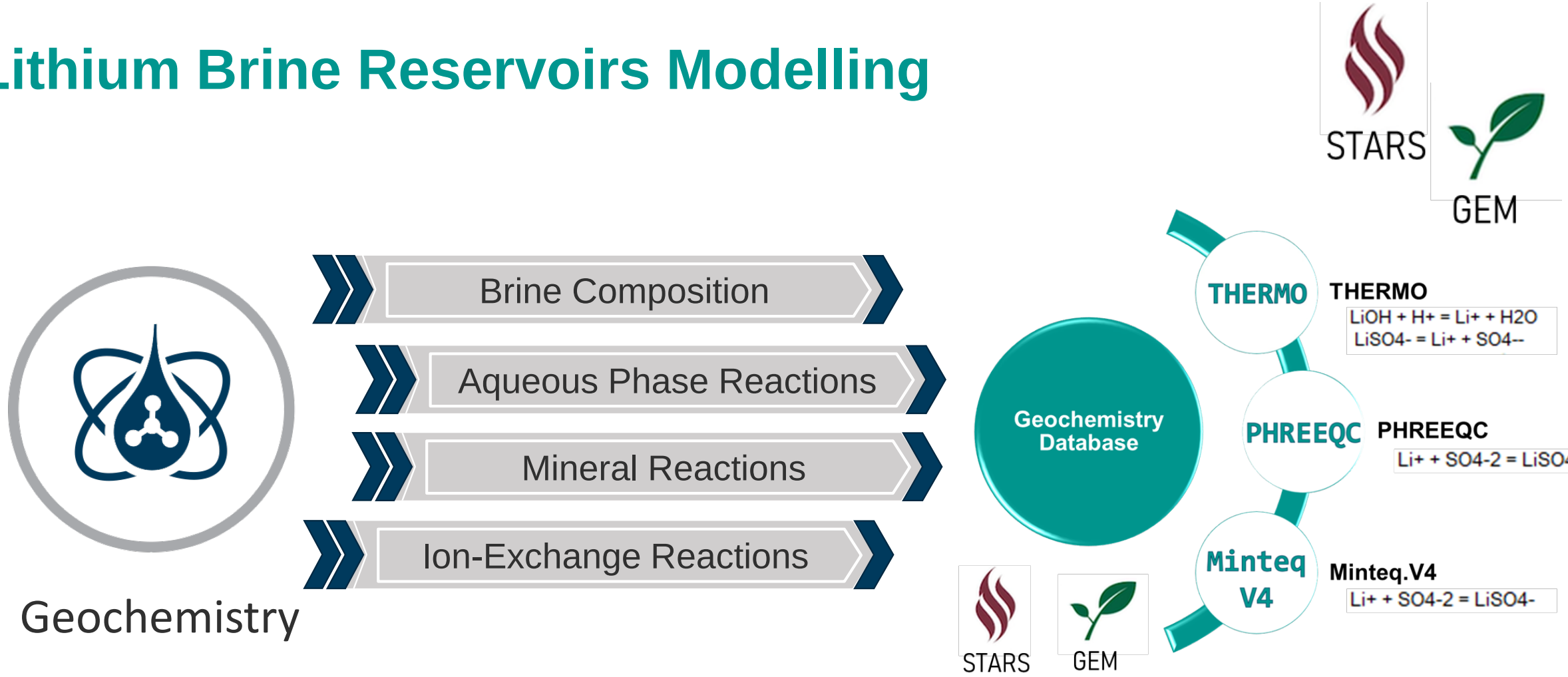
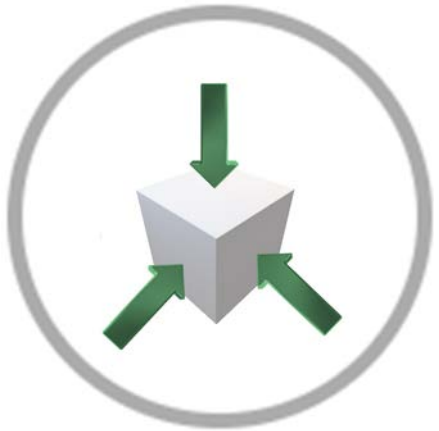
# Lithium Brine Reservoirs Modelling



STARS

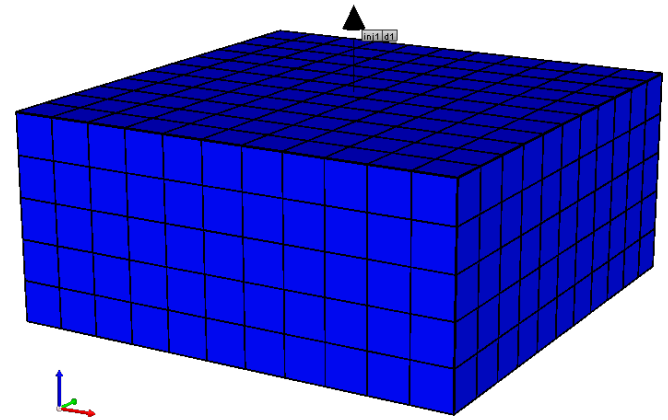
Geothermal

- Heat Transfer Effects
- Wellbore conduction and convection
- Effects in the Brine Quality



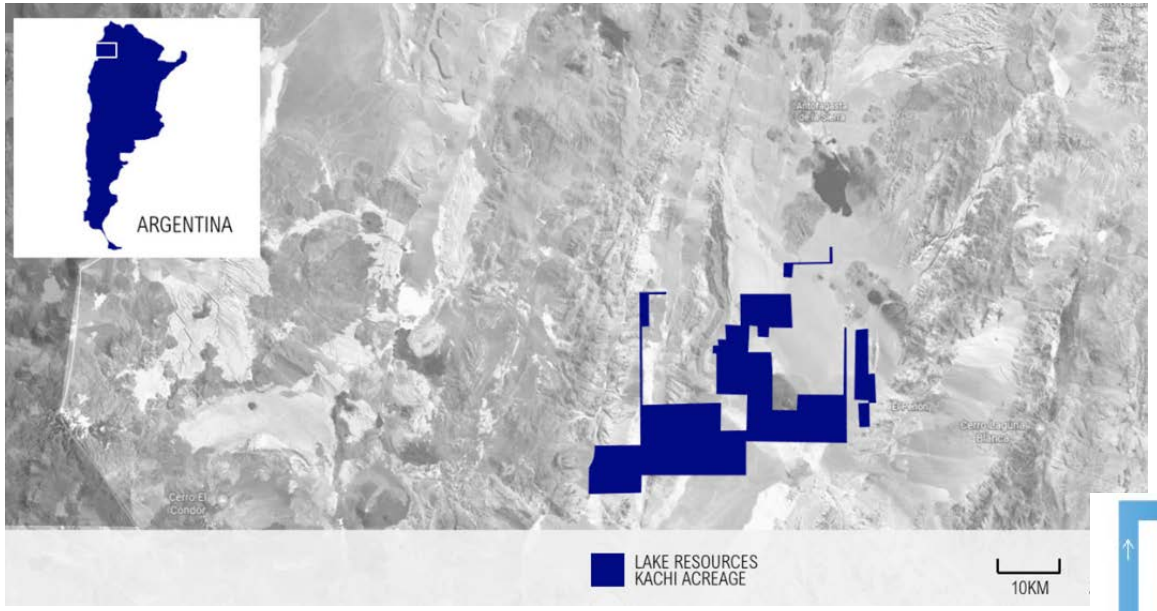
# Geomechanics

- Geomechanical properties dependent on porosity and solid components
- Stress-induced phenomena, collapse of formation near the well, and elastic or plastic deformation
- Mechanistic models of compaction and 3D dilation to study the effect of stress on porosity
- The direct relationship between stress and fracture or matrix permeability



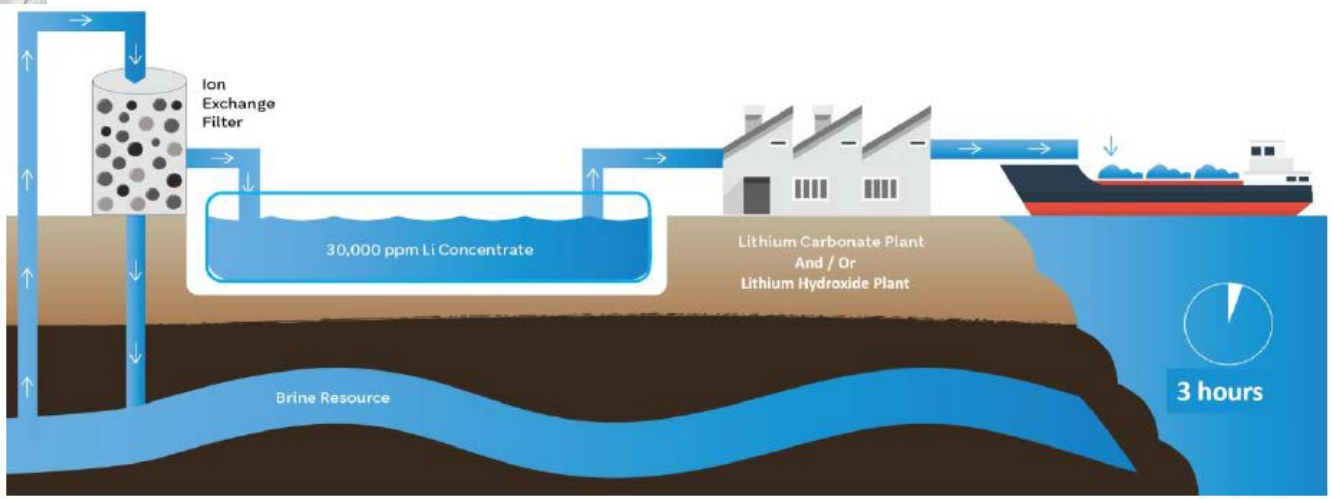
# Example

# Kachi Lithium Brine Project



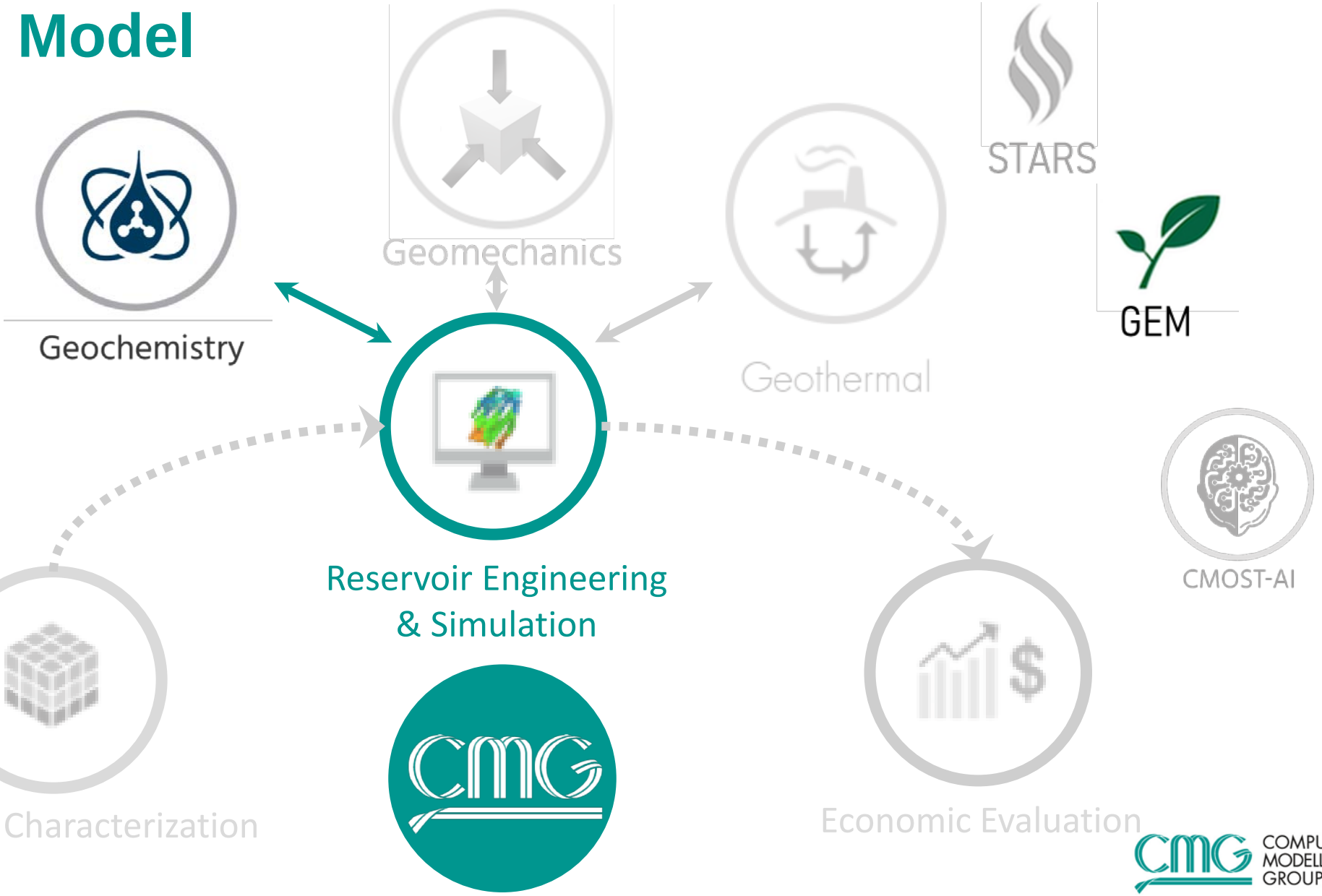

Litio Catamarca: Lake Resources avanza con la factibilidad de Kachi - Mining Press

## Extraction scheme
### Ion Exchange Lilac Solutions

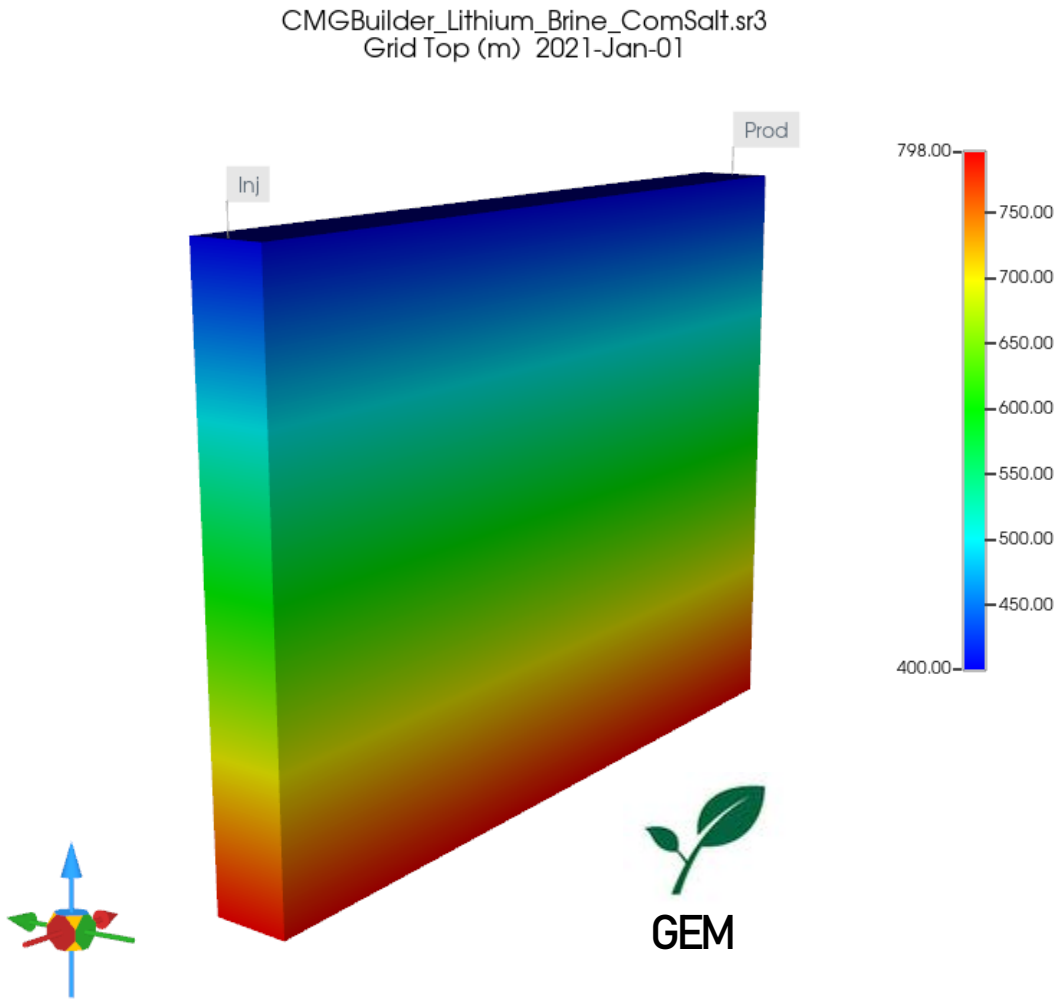



PRESS RELEASE: Pilot Plant Engineering Underway at Kachi Lithium Project — Lilac Solutions: Lithium Extraction

# Conceptual Model



# Model Description




Cartesian Grid 100 x 1 x 200

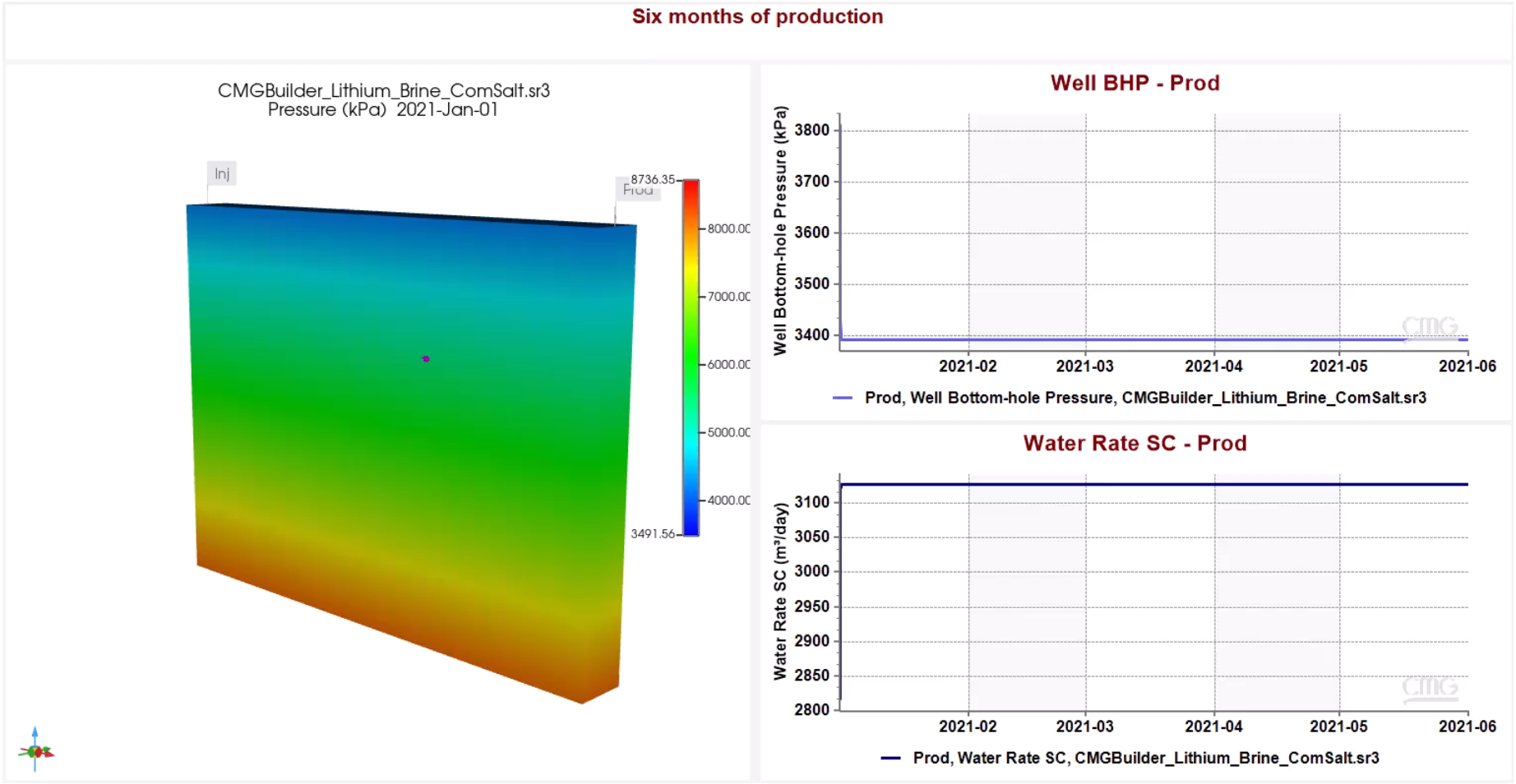
Porosity: 8%

Permeability: 500 mD

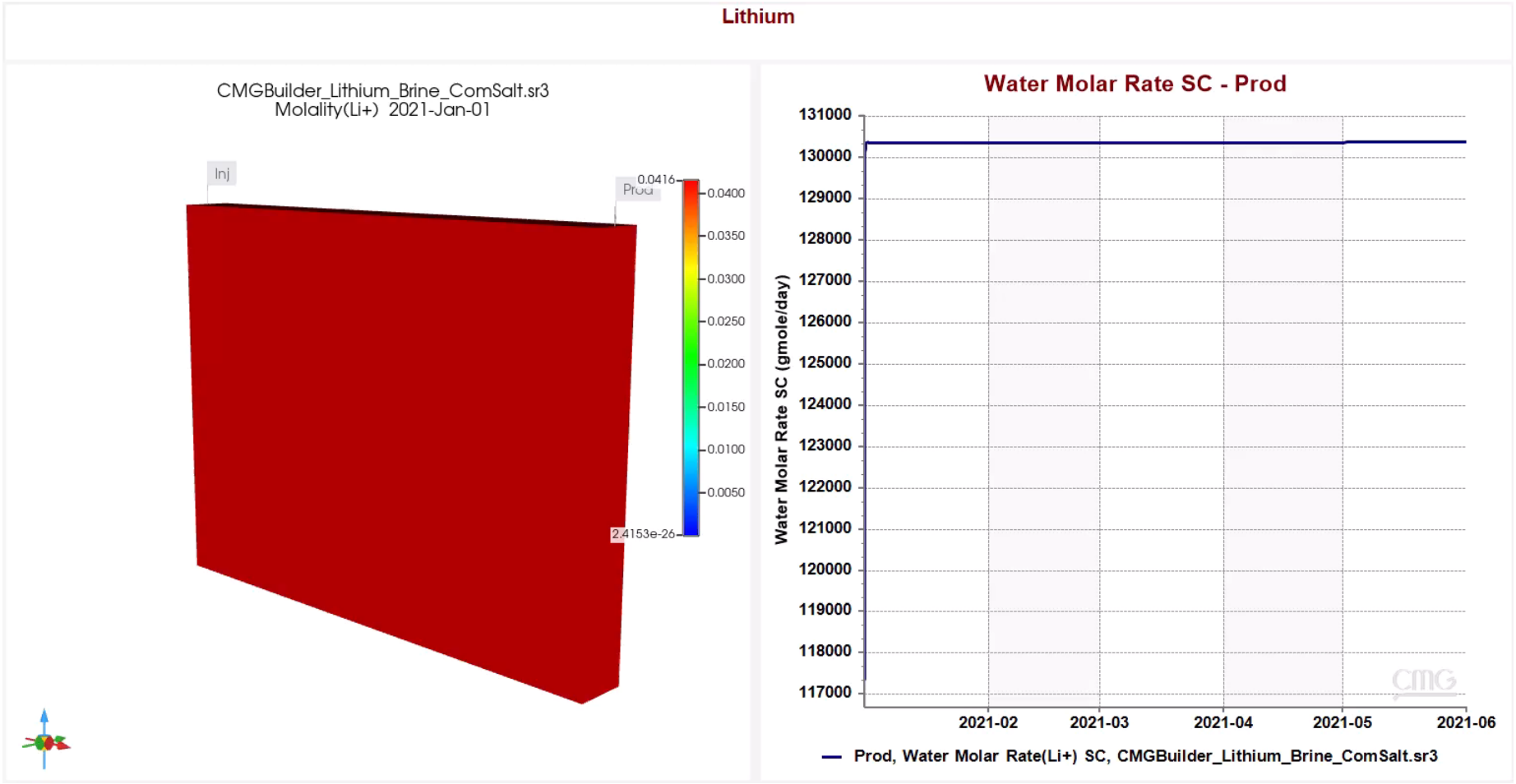
Aqueous components

- Magnesium 76 ppm
- Potassium 5000 ppm
- Chlorine 1000 ppm
- Sodium 1000 ppm
- Lithium 289 ppm

# Results


Six months of production
CMGBuilder_Lithium_Brine_ComSalt.sr3
Pressure (kPa) 2021-Jan-01
Inj
Prod
8736.35
8000.0C
7000.0C
6000.0C
5000.0C
4000.0C
3491.56
Well BHP - Prod
Well Bottom-hole Pressure (kPa)
3800
3700
3600
3500
3400
2021-02
2021-03
2021-04
2021-05
2021-06
Prod, Well Bottom-hole Pressure, CMGBuilder_Lithium_Brine_ComSalt.sr3
Water Rate SC - Prod
Water Rate SC (m³/day)
3100
3050
3000
2950
2900
2850
2800
2021-02
2021-03
2021-04
2021-05
2021-06
Prod, Water Rate SC, CMGBuilder_Lithium_Brine_ComSalt.sr3

# Results


Lithium
CMGBuilder_Lithium_Brine_ComSalt.sr3
Molality(Li+) 2021-Jan-01
Inj
Prod
0.0416
0.0400
0.0350
0.0300
0.0250
0.0200
0.0150
0.0100
0.0050
2.4153e-26
Water Molar Rate SC - Prod
Water Molar Rate SC (gmole/day)
131000
130000
129000
128000
127000
126000
125000
124000
123000
122000
121000
120000
119000
118000
117000
2021-02
2021-03
2021-04
2021-05
2021-06
Prod, Water Molar Rate(Li+) SC, CMGBuilder_Lithium_Brine_ComSalt.sr3

# Results

| Total Component Amounts in Reservoir | | Moles | kg |
|---|---|---|---|
| Aqueous Components | | | |
| | Mg++ | = 2.51125E+06 | 6.10359E+04 |
| | K+ | = 1.03155E+08 | 4.03317E+06 |
| | Cl- | = 2.26603E+07 | 8.03375E+05 |
| | Na+ | = 3.49449E+07 | 8.03375E+05 |
| | Li+ | = 3.34263E+07 | 2.32012E+05 |

Cumulative Field Total at Reservoir Conditions for Components.....

| Comp | Cum Inj gmole | Cum Prod gmole | Accum gmole | Acc/(Inj-Pro) | Recovery % | Error mol in place,% |
|---|---|---|---|---|---|---|
| FC7 | 0.00000E+00 | 5.72848E-04 | -5.72829E-04 | 9.99967E-01 | 9.41547E-06 | 3.13276E-10 |
| H2O | 2.62345E+10 | 2.62358E+10 | -1.16633E+06 | 8.99512E-01 | 5.88904E+01 | 1.84073E-04 |
| Mg++ | 1.47881E+06 | 1.47888E+06 | -6.57447E+01 | 8.99512E-01 | 5.88904E+01 | 1.84073E-04 |
| K+ | 6.07451E+07 | 6.07481E+07 | -2.70060E+03 | 8.99512E-01 | 5.88904E+01 | 1.84073E-04 |
| Cl- | 1.33441E+07 | 1.33447E+07 | -5.93249E+02 | 8.99512E-01 | 5.88904E+01 | 1.84073E-04 |
| Na+ | 2.05782E+07 | 2.05792E+07 | -9.14860E+02 | 8.99512E-01 | 5.88904E+01 | 1.84073E-04 |
| Li+ | 0.00000E+00 | 1.96849E+07 | -1.96848E+07 | 9.99995E-01 | 5.88904E+01 | 2.70761E-04 |

# CMOST

CMOST-AI

- Well allocation for producer and disposal wells
- Operational conditions

# Conclusions

- CMG's technology can be used to model both oil and gas reservoirs, as well as to model other types of reservoirs that are part of the global energy transition.
- Both GEM and STARS can be used to simulate lithium brine reservoirs
- With CMG you can combine energy transition technologies such as geothermal and lithium production
- Companies can use CMG to assess the increase in profits from the exploitation of lithium in oil and gas fields
- With CMOST you can design and optimize your lithium reservoir development plan

# Acknowledgment


- Varun Pathak
- Argenis Alvarez

**CMG's Vision:**

To be the leading developer and supplier of dynamic reservoir and production technologies in the WORLD

## Contact

For more information please contact **info@cmgl.ca**

## R&D Investment

CMG reinvests 20% annual revenue back into R&D, to further innovation and drive technology forward

## Superior Software

CMG delivers easy to use software that provides the most accurate results

## Dedicated Support

Experienced technical sales & support personnel, deliver high-quality, timely and personalized customer support

## Relevant Training

CMG's industry renowned reservoir software training provides the skills to improve productivity and efficiency