Brine Mining

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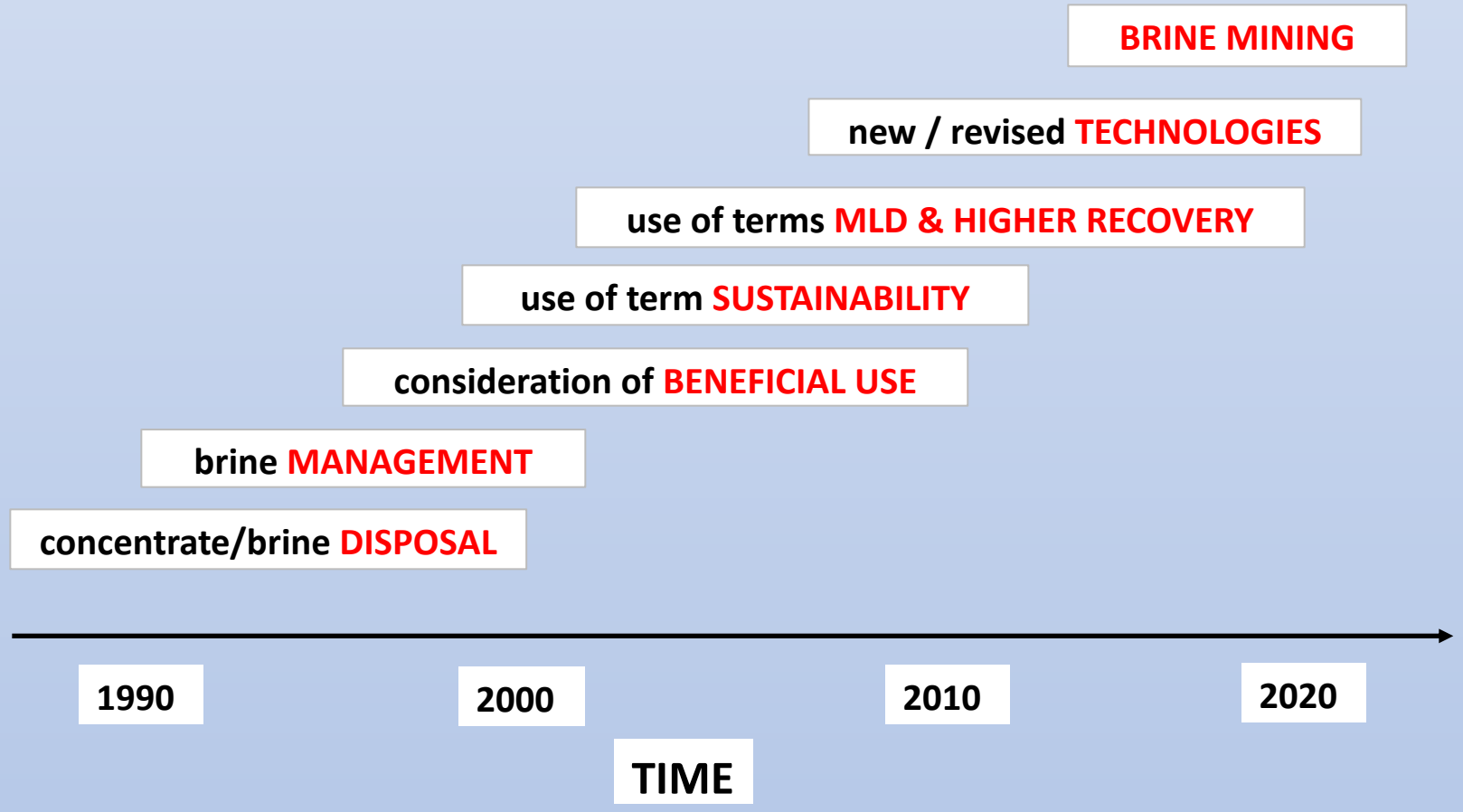
Evolution of Brine Management

(when areas reached a major stage of consideration)



Commercial Milestone Events in Brine Mining

(from the author's perspective and bias)

- **Salt recovery from evaporation ponds (thousands of years)**
- **ZLD recovery of salt from individual salt dominated waters (since mid/late 1900's)**
- **Geo-Processors – Sydney (2000 →)**
- **Enviro Water Minerals – El Paso (2010 →)**
- **Saudi (NOEM/Jubail) and European projects (2018 →)**

NOTE: Much non-commercial research: it is relatively easy to produce salts BUT difficult to produce salts of a given purity and grain size.

CURRENT (& recent) MAJOR BRINE MINING EFFORTS

Saudi efforts

- **NOEM and Jubail** (135 and 264 mgd) – mandate from Saudi government

NOEM

- **New town of 1M people**
- **All renewable energy**
- **Near ZLD desalination**
- **Extensive brine mining**

European consortiums:

- **Sea4Value** (treating seawater)
- **Zero Brine** (treating wastewater from textile manufacturing, coal mining, silica mining, and municipal facilities
- **Water Mining** (treating seawater, mining wastewater, and municipal wastewater)
- **HighCon** (treating organic laden industrial wastewaters)
- **EasyMining AB** (treating fly ash leachate)

Several recent conferences:

- **International Specialty Conference on Ocean Brine Mining** (March, 2022 in Al Khobar, Saudi Arabia)
- **Global Water Summit** (May, 2022 in Madrid, Spain)
- **Innovation Driven Desalination on Brine Mining** (Jane, 2022 in Jeddah, Saudi Arabia)
- **EDS Conference: Desalination for the Environment** (June, 2022 in Las Palmas, Spain)


Day 21, no one suspects a thing

BRINE MINING

(brine mgt tool)

BROAD DEFINITION USED:

-- mining from any water:

- **seawater**
- **brackish water**
- **municipal wastewater**
- **industrial wastewater**

OTHER TERMS USED:

-- valorization
-- water mining
-- water refining
-- value-based recovery

TYPES OF RECOVERABLE MATERIALS:

-- for direct use (e.g., $CaCO_3$)
-- for simple conversion to products (e.g., Mg^{+2} to $Mg(OH)_2$)
-- for more complex conversion to products (e.g., Mg^{+2} to Mg metal)
-- for use in making complex products (e.g., Cu, Zn, Ni, Li, etc. for use in electronics)

DRIVERS:

-- economic: recovery of materials for use or sale
-- environmental: both regulatory and for sustainable practice
-- corporate: reduce risk and liability related to transport and disposal; possible option to importing

POSSIBLE BENEFITS:

-- reduce desalination costs
-- reduce waste
-- detoxify waste
-- reduce carbon footprint
-- reduce lost water
-- avoid importing materials
-- societal (circular economy)
-- provide management solution

Historically the largest driver

But there are avoided costs

BARRIERS:

Feasibility
-- feasibility determination (lengthy and costly process; complex chemistry)
-- site-specific feasibility (chemistry, volume, market)
-- technical and market considerations

Market aspects
-- competition with virgin sourced materials (typically large scale)
-- volatile pricing, demand, and markets

TECHNOLOGIES:

- Similar/same as removal technologies
- BUT recovery typically requires additional processing of materials to meet product use specifications (form, size, purity)
- General approaches:
  - Selective precipitation
    - Mainly desalination
    - In development: Exclusion (freezing, H2O absorption)
  - Ion specific extraction - possible prior concentration
  - Nanofiltration (NF) in front of RO

MARKET ISSUES

- **Market size** (Billion $/yr & kg/yr)
  - Depends product purity and grain size
- **Product price ($/kg)**
- **Market location** (regional, local)
- **Market changes**
  - Volatile pricing
  - Demand
  - New sources of product
- **Market competition**
  - Traditionally sourced materials
  - Evolution of final product makeup
- **May have to create new markets**

Global market (B$/yr)

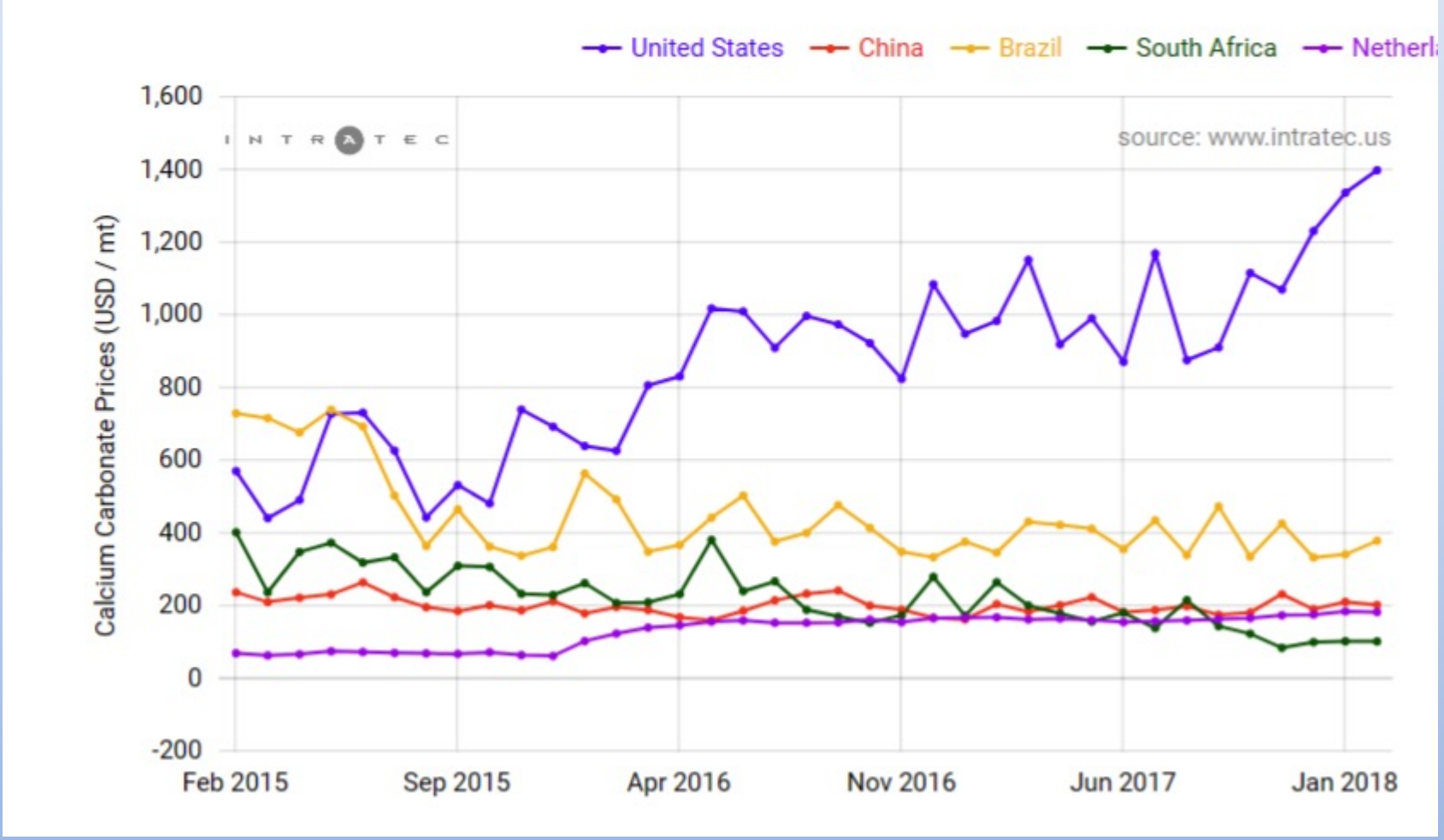
Element/Compound	Estimate date	Estimated global market size (USD billions)
Calcium carbonate	2021	42.5
Sulfite	2020	32.72
Halite	2020	28.6
Lithium	2021	6.83
Magnesium	2021	4.39
Calcium chloride	2020	1.89
Soda ash	2020	1.63
Potassium nitrate	2020	1.56
Magnesium hydroxide	2022	1.0
Hydrochloric acid	2020	0.95

Global unit price ($/kg)

Element	Unit Price ($/kg)
Rubidium	14.50
Iodine	25.10
Lithium	6.31
Bromine	3.98
Magnesium	1.91
Sodium hydroxide	0.89
Potassium	0.63
Magnesium sulfate	0.56
Hydrochloric acid	0.45
Boron	0.40
Potassium chloride	0.28
Magnesium chloride	0.28
Sodium chloride	0.22
Calcium carbonate	0.20
Sodium	0.17
Calcium sulfate	0.13
Strontium	0.05
Calcium	0.03

CALCIUM CARBONATE PRICES (2015-2018)

(USD/mt)



Unit prices are location dependent

FEASIBILITY DETERMINATION

- **Determination of possible product(s)**
  - **Dependent on source water (relative abundance)**

- **Determination of technical approach to obtain products(s)**
  - **Need sophisticated software for high salinity solubility predictions**
  - Initial research / simulations (does not include kinetics)
  - **Bench scale testing (to confirm)**
  - Piloting (if beyond screening stage feasibility)
  - Process optimization

- **Evaluation of market**
  - Market assessment
  - Product package
  - Product specification
  - Product yield
  - **Marketing approach (what entity will sell products)**

Take-home Points

- Significant growing interest in mining seawater, brackish water, industrial sources, & others
- Still relatively early in definition of issues – lack of clarity
- Drivers and benefits increasingly considering 'avoided costs'
- Technologies exist and new versions are being developed
- Feasibility very location and source water dependent
  - Volume, concentrations, complexity
  - Note – not quite so with seawater
  - For inland water sources, brine mining is an area to watch. For some it is an area to consider – including consideration of avoided costs. For many, it may not be feasible.