

Introduction

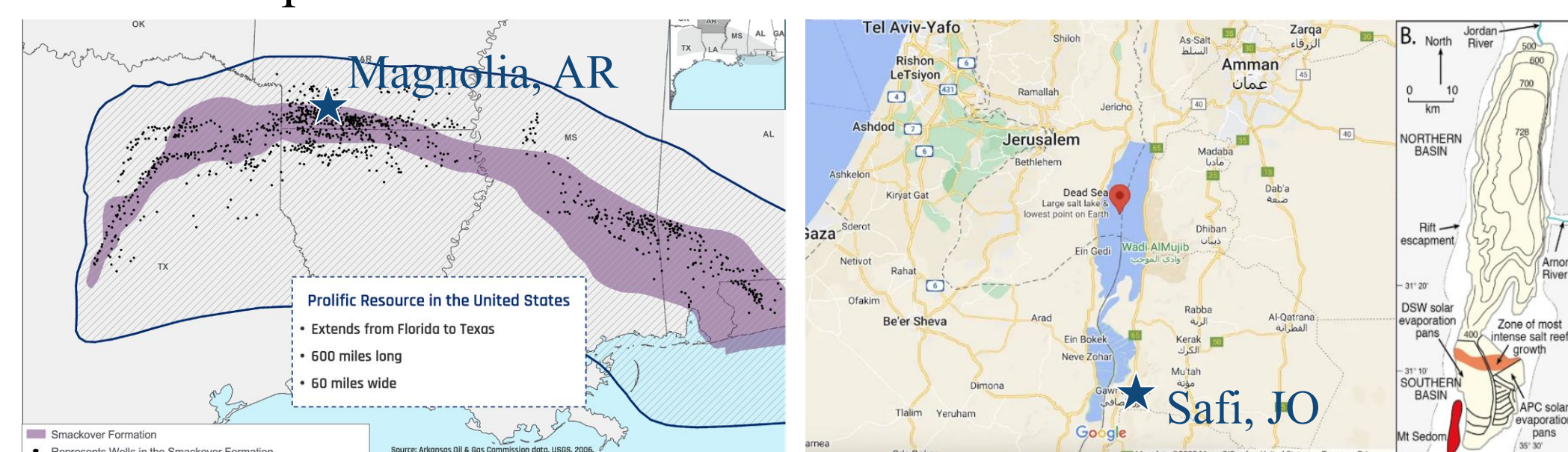
- Applications of bromine:
 - Brominated flame retardants (BFR) for automotive industry, electronics, furniture
 - Mercury emission reduction in coal burning and waste incineration
 - Energy generation and storage
- Elemental bromine is not naturally occurring; it is found primarily as bromide ion in salt brines
- Annual bromine production today and projected:
 - 2024: 500,000 tons
 - 2035: 820,000 tons

Objective

- Research and design a chemical production plant to produce bromine from bromide-containing brine
- Develop a +/- 50% economical evaluation of the plant total module cost, payback period, and yearly gross revenue

Methods

Location Options



Technology Options

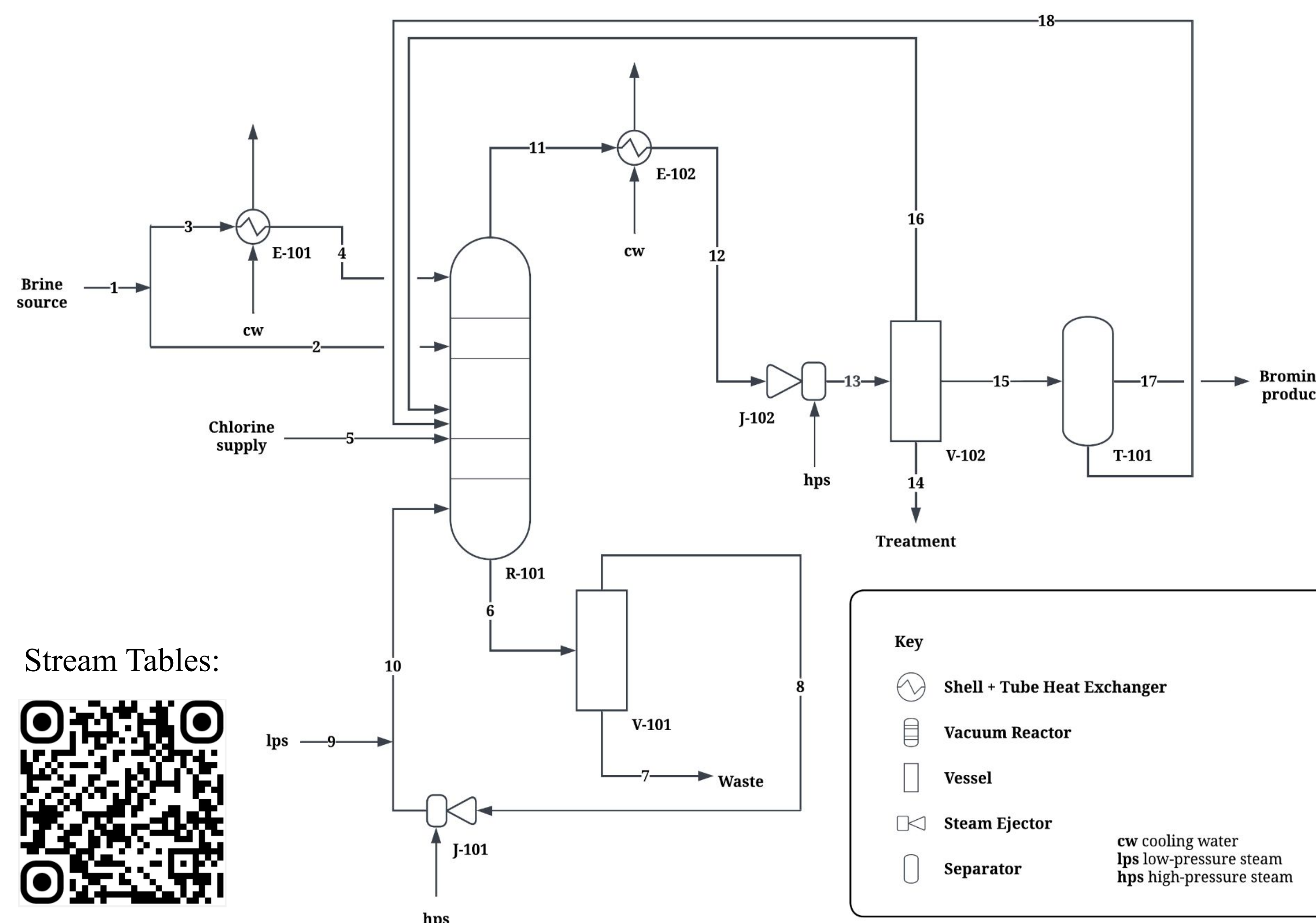
- Chlorine Oxidation
 - $2\text{NaBr} + \text{Cl}_2 \rightarrow 2\text{NaCl} + \text{Br}_2$
- Peroxide Oxidation
 - $2\text{NaBr} + \text{H}_2\text{O}_2 + \text{H}_2\text{SO}_4 \rightarrow \text{Br}_2 + 2\text{NaOH} + \text{H}_2\text{SO}_4$
 - $\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$
- Electrolysis
 - $2\text{NaBr} \rightarrow 2\text{Na}^+ + 2\text{e}^- + \text{Br}_2$
 - $2\text{H}_2\text{O} + 2\text{e}^- \rightarrow 2\text{H}_2 + \text{OH}^-$

Sustainability

- Compliance with state-level emissions regulations was evaluated
 - No air emissions, but water emissions are out of compliance
 - Activated carbon filter recommended to reach compliance

Source	Water (tons)	Electricity (kWh)	Carbon dioxide (tons)
Magnolia, AR	1,510,000	37,500,000	220,000
Bromine plant	108,000,000	6,830,000	55,400

Process Flow Diagram



Stream Tables:

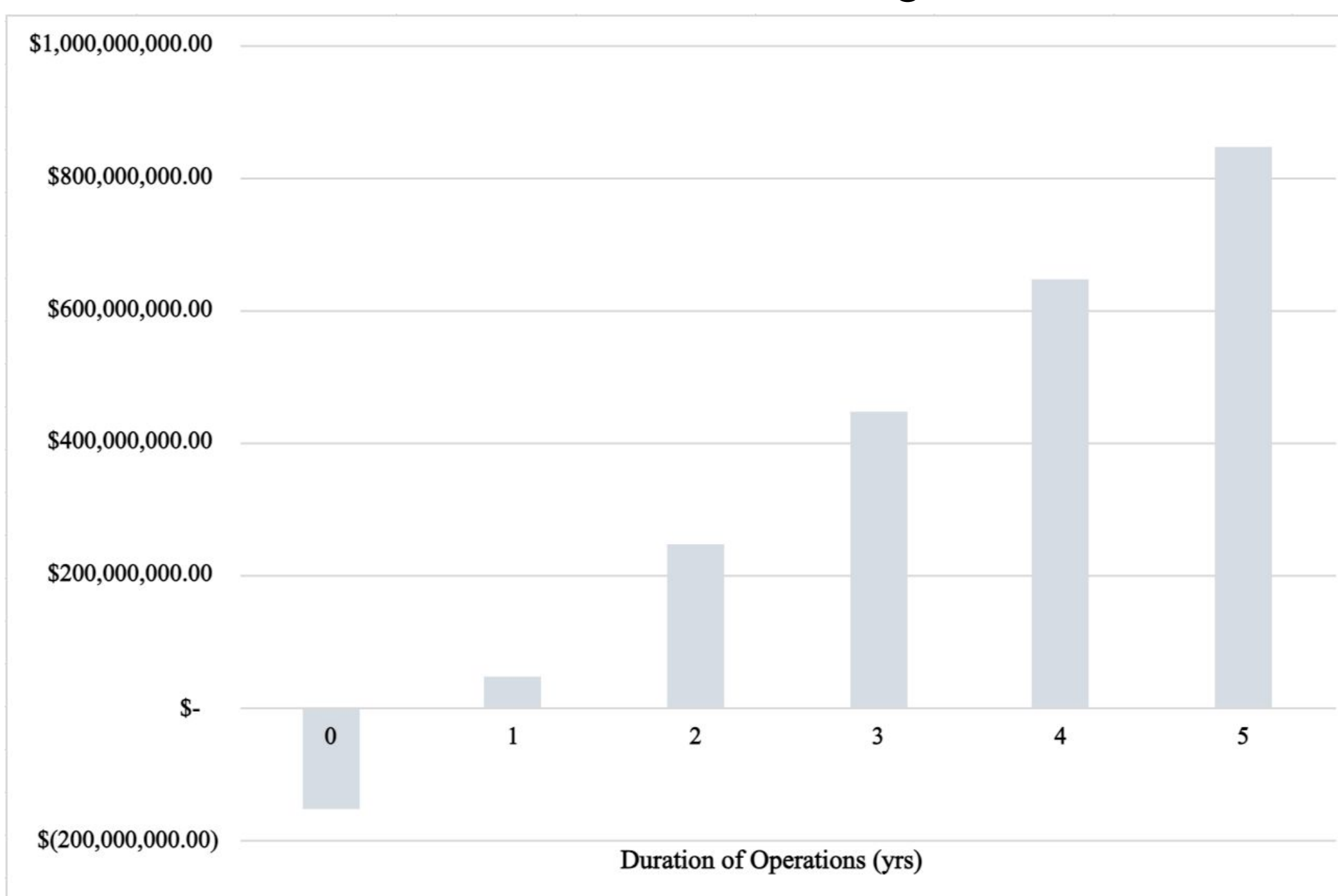


Equipment Summary Table

Equipment	Description	Cost
E-101	Brine Cooler	\$1,051,800
E-102	Distillate Partial Condenser	\$501,800
R-101	Vacuum Reactive Stripping Tower	\$30,551,400
V-101	Flash Separator for Bottoms	\$316,700
V-102	3-Phase Separator	\$96,200
T-101	Bromine Purification Column	\$82,900
J-101	Vacuum Generator 1	\$62,200
J-102	Vacuum Generator 2	\$1,600

Economics

Cumulative Cash Flow Diagram



Key Economic Metrics:

- Total Equipment Cost
 - \$32,663,600
- Total Module Cost
 - \$154,825,500
- Payback Period
 - 0.77 Years

Hazards

- Process hazard analysis completed through the use of a Hazard and Operability study (HAZOP)
- Process hazards include chemical hazards, explosion/implosion, and process conditions
- Chemical compatibility study revealed incompatibilities due to exothermic reactions, corrosion, and toxic chemicals
- Reactive hazards screening should be completed to ensure material of construction is fit for process conditions
- Mitigative action:
 - Routine cleaning
 - Equipment inspection
 - Passive pressure control (pressure relief valves)
 - Redundant temperature control (back-up cooling systems)
 - Flow control

References



Category	Item	Cost per Unit	Amount	Cost per Day
Raw Materials	Chlorine	\$0.18/lb	11,000 lb/h	\$47,500
	Brine	\$2,500,000/yr	6,700,000 lb/h	\$6,800
Operational Costs	Labor	\$69,500/yr	12 operators	\$2,300
	Utilities	\$2,200/h	24 h	\$52,800
Products	Bromine	\$1.36/lb	22,000 lb/h	\$718,000
<i>Gross Profit</i>				\$608,700