Chlor-Alkali LCA

Goal

Determine the environmental impact of the process of generating higher concentrations of hydrochloric acid, sodium hydroxide, and hydrogen from brine and saltwater solutions. By using the LCA framework, the objective is to evaluate the environmental impacts for three life cycle impact categories: energy usage, carbon footprint, and water usage. Further evaluation and understanding of these impacts will provide insight for decision-making and future improvements. While there are preliminary results to mimic scaling up the process that was conducted on a lab scale, this report should provide insight on the feasibility in other contexts.

Scope

The scope of this LCA will be solely focused on the process- meaning that the raw material extraction and end of life components of the system will not be the primary components of emphasis. In the diagram, only the DE MnMo system will be taken into consideration for analysis. The system boundaries are the exterior of the processes (the exterior of the membrane, cathode-anode & electrochemical cell tank), as shown in Figure 1. As the primary purpose of the system, in the context of the lithium project proposal, was to produce hydrochloric acid, the functional unit will be 1 metric ton, or 1000 kg of hydrochloric acid produced from the process.

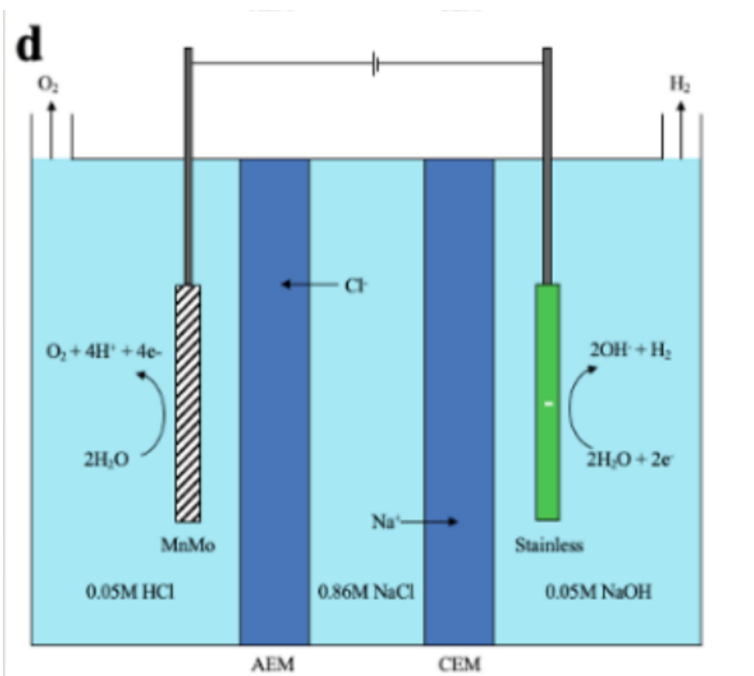
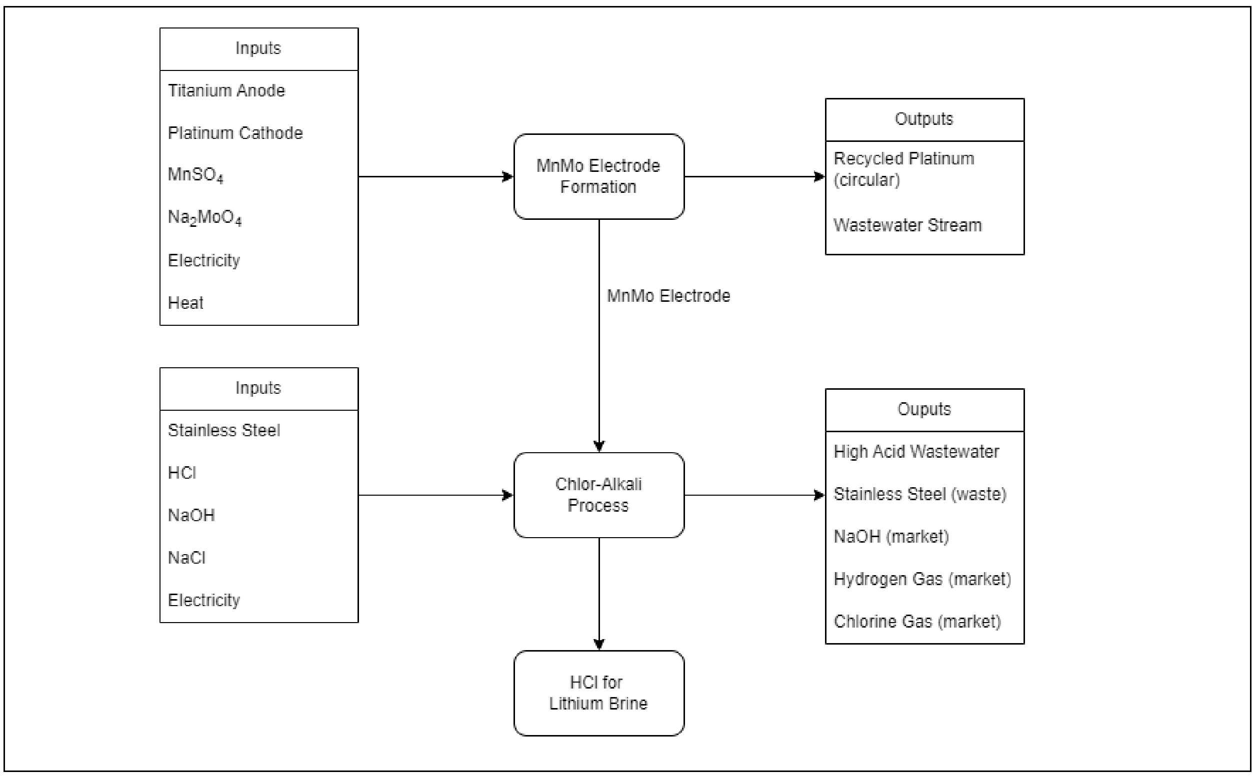


Figure 1: Proposed Schematic

Life Cycle Inventory

As the process for producing hydrochloric acid involves the creation of the MnMo electrode, the life cycle inventory assessment has two processes:

1. The formation of the MnMo electrode, which produces the MnMo electrode for the chlor-alkali process, platinum that can be reused several times for making MnMo electrode, given heat, electricity, a titanium anode, and solutions of manganese sulfate and sodium molybdate.
2. The chlor-alkali process, which produces hydrochloric acid along with sodium hydroxide, hydrogen gas, chlorine gas, given low concentrations of hydrochloric acid, sodium hydroxide, along with a sodium chloride solution, a stainless steel anode, and electricity.



The mass balance calculations for this life cycle inventory, as subjected to 1 kg of hydrochloric acid can be found in this Process Calculations spreadsheet. The numbers were further scaled up to 1000 kg for conducting the Life Cycle Impact Assessment.

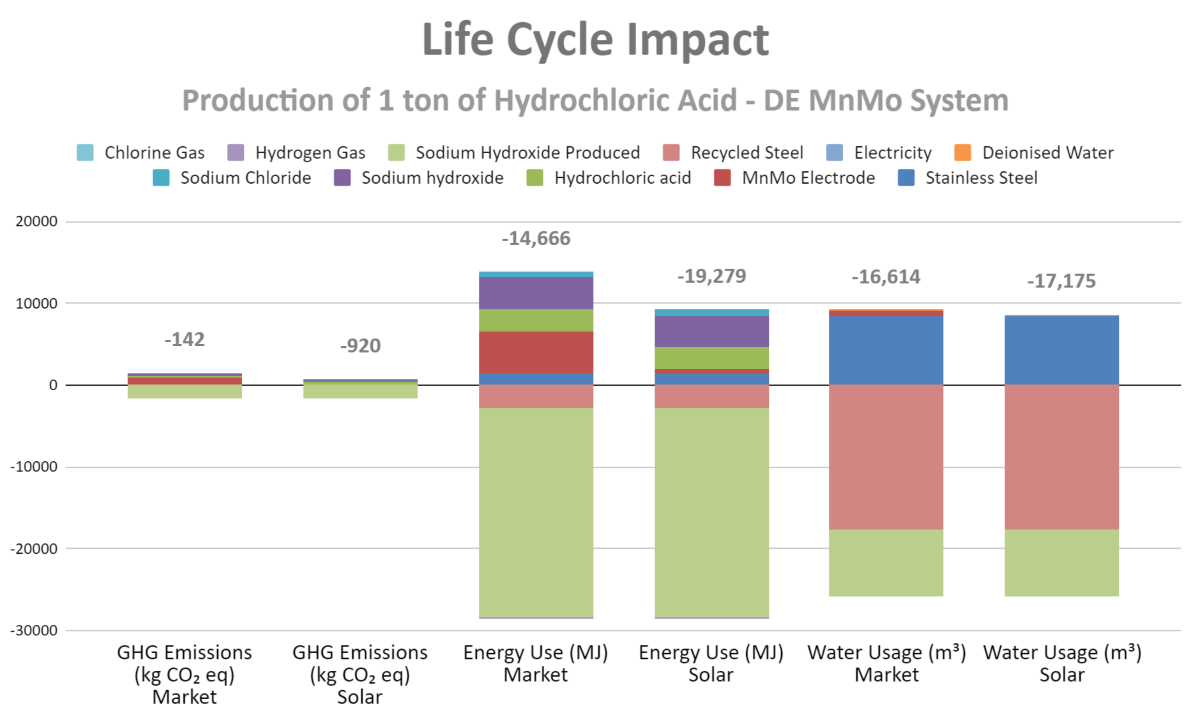
Life Cycle Impact Assessment Results

The following assumptions & limitations apply to this analysis:

- Each process results in the generation of a new titanium anode being used for the MnMo electrode formation - the potential for recycling the used MnMo electrode was not considered for analysis.

- As the platinum cathode can be recycled several times in this process, it was not included in this process scale LCA. It will need to be considered when doing a cradle-to-gate, full life cycle analysis.
- As there has been work centered around the recycling of steel & titanium, stainless steel is assumed to be recycled and sold to the market as slag from this process.
- The manganese sulfate and sodium molybdate solutions are assumed to be produced for each process- a recycling stream has not been considered. Similarly, this analysis does not include the handling of the wastewater from this process.
- Sodium hydroxide, hydrogen, and chlorine are all assumed to be stored and sold to the market
- This LCA Analysis is conducted based on data done on the laboratory scale- there will be no sensitivity or risk analysis for different yield components.
- Environmental impacts for the creation and end of life for the functional blocks (i.e. AEM membrane, CEM membrane) will not be utilized for this LCA model. Only impacts and resources needed for use of this experiment will be included.
- Transportation will not be included in this LCA model ~ the environmental impacts involving the transportation of raw materials and the recycling of the lithium-depleted brine will not be considered in this analysis.

Two scenarios were run for results - one for market based energy and another for solar energy. The LCA model was developed in SimaPro 9.4.0.2 using the method IMPACT World+ Midpoint 1.2. Three impact categories are considered for analysis: Climate change measured based on Global Warming Potentials on a 100-year time frame (GWP100) in kg CO_2-equivalents, fossil and nuclear energy use measured in MJ deprived, and water scarcity impact measured in m^3 world equivalent.



Interpretation of Results

From an initial view, the results of the process from an environmental perspective, indicate that this process is feasible on a larger scale. The greenhouse gas emissions suggest that this process can achieve carbon neutrality or even carbon negativity from market energy or solar energy. However, these results should be peer reviewed and an uncertainty analysis should be conducted on the other components of this research project. As for the energy usage, the byproduct of sodium hydroxide suggests that the energy usage or the MJ deprivation of the DE MnMo system is environmentally friendly. Finally, for water usage, steel must be recycled to have a net negative impact.

A decision maker should have fair certainty that this Life Cycle Impact Assessment has relatively positive environmental impact. Further research on the recycling of steel from old membranes should be considered and future LCAs should be conducted that are more rigorous on assumptions.