Lithium Pathway Updates and Additions in the GREET ® Model

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Summary

The purpose of this document is to provide an update to the structure of lithium production pathways within the GREET model. Specifically, this update will introduce pathways for lithium extracted from spodumene ore and converted into lithium carbonate (Li_2CO_3) and lithium hydroxide (LiOH). Within the GREET model, no numerical data will be provided for these ore-based pathways. The brine-based lithium pathways will be retained, but modifications to the calculation methods of some precursor materials will be integrated. However, these do not impact any current data for the lithium pathways presently in GREET. The impetus for this update is a forthcoming release of a lithium production pathways report that will provide the numerical basis to populate the new and updated pathways.

1. Organization

All brine-based production is now organized onto a new Lithium tab with GREET2020. Some of the calculations and data were previously in the LiMn2O4 and Other_Cathodes tabs, but they have been migrated together for a more cohesive Lithium tab that is then used to inform each of the other tabs. The brine and ore end products are Li_2CO_3 and LiOH. These brine and ore-based pathways are now used in combination to develop an average for both Li_2CO_3 and LiOH depending on the specified percentage of each type for the market.

2. Updates for brine-based lithium pathways

2.1 Electricity

Within this update, the electricity grid for lithium production will now be separated from the Chilean mix. This allows for users to modify the electricity basis for brine-based lithium

production while retaining the Chilean electricity grid for other purposes. We will set this new electricity grid to have the same mix as Chile, whose grid has been updated to 2018 based on data from the World Bank and International Energy Administration (IEA), Table 1 (The World Bank 2018; International Energy Agency 2020) .

Table 1. Electricity generation mix and T&D loss of electricity for lithium production in Chile (average grid and grid for lithium production).

		Electricity mix						
Grid	**T&D loss**	**Coal**	**Oil**	**Natural gas**	**Nuclear**	**Hydro**	**Biomass**	**Other**
Chile (Average)	6.7%	35.7%	1.7%	15.6%	0.0%	28.7%	7.3%	11.0%
Chile Grid for Lithium	6.7%	35.7%	1.7%	15.6%	0.0%	28.7%	7.3%	11.0%

2.2 Transmission and Distribution of Materials

To allow more flexible incorporation of material transportation that are more closely match with industry, we have modified the source of lime to no longer be specific to Chile and we have added a transportation stage by Ocean Tanker in addition to the Heavy Duty Truck. At present, we retain the previous assumption that the Ocean Tanker transit distance is zero miles. This allows future flexibility. We also add transportation pathways (Ocean Tanker and Truck) for LiOH produced from a brine source in Chile that would be distributed to battery cathode producers.

3. Development of ore-based lithium pathways

Ore-based lithium is available from Western Australia and represents a significant market share of global lithium production. This form of lithium is spodumene from mined ore. The USGS notes that Australia was the leading producer of lithium mineral concentrates. Australian lithium production has grown significantly in the past decade and now accounts for 54% of total world lithium production, but it has historically shipped its concentrates to other locations for refining (U.S. Geological Survey 2019). Spodumene ($LiAlSi_2O_6$) contains up to 8% LiO_2 (by mass) which can be refined to obtain lithium chemicals, such as Li_2CO_3 or LiOH, or it can be used directly for ceramic, glass, and metallurgical applications. Historically, the lithium sourced in Australia has been used within those ceramic, glass, and metallurgical applications. In more recent years, there has been interest in the production of Li_2CO_3 or LiOH from spodumene for use in the battery cathode industry. We add the structure for these pathways to GREET to allow for future development and population of the data.

3.1 Spodumene Concentrate from Ore

There are several desirable lithium mining locations within Western Australia. The process of lithium extraction is generally open-cut mining from a site where it is then reduced in size through a series of crushing and milling stages followed by a series of flotation stages that allow for separation of the valuable spodumene from various tailings (Wietelmann and Steinbild 2014). The spodumene concentrate is then transported to its next stage of production, here, we are focused on Li_2CO_3 or LiOH as the final product.

3.2 Li2CO3 from Ore

The details of Li_2CO_3 are not presented here. However, Wietelmann and Steinbild identify that size reduction, roasting, leaching, and several stages of precipitation and filtration are required and that there are additions of several chemical reagents in the process (2014). We develop the analysis structure for a facility level analysis with inputs of energy, water and material associated with the final production of Li_2CO_3 from spodumene concentrate.

3.3 LiOH from Ore

Again, the details of LiOH production processes are not presented in detail here. But, Wietelmann and Steinbild identify that size reduction, roasting, leaching, and several stages of precipitation and filtration are required and that there are additions of several chemical reagents in the process (2014). We develop the analysis structure for a facility level analysis with inputs of energy, water and material associated with the final production of LiOH from spodumene concentrate.

3.4 Materials

For each process there are materials needed to convert the original material into the final product. The materials input table for the Lithium tab will contain all necessary materials for the production of each product that is detailed on the Lithium tab and is shown in Table 2. Two materials that are not within GREET, oleic acid and diatomaceous earth, are included in this list, and materials pathways for each material are included but not developed. Those pathways thus indicate zero burden.

Table 2. List of material inputs for processes within the GREET Lithium tab

Materials Used on Lithium Tab
H_2
Hydrochloric acid (HCl)
Soda Ash (Na_2CO_3)
Concentrated Lithium Brine
Lime
Organic solvent
Sulfuric acid (H_2SO_4)
Alcohol
Citric Acid
Hydrogen Peroxide (H_2O_2)
NMP
Lithium
Limestone
Manganese in manganese ore
Li_2CO_3
Mn_2O_3
Sodium hydroxide
Dispersant (Diesel)
Oleic Acid
Spodumene concentrate
Diatomaceous earth

3.5 Electricity

As noted, the mining location for this process is Australia, thus mining associated electricity is assigned to the Australian grid. However, Australia does not currently process this lithium into cathode precursors or cathode materials. There are currently construction activities for the development of an LiOH production facility in Australia, but those are not yet complete. Electricity to produce Li_2CO_3 and LiOH are based on the Chinese grid since China is a major producer of ore-based lithium products.

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