Evergreen International Sustainability Solutions LLC was contracted by Earthworks to provide a 3rd party assessment of the Greenhouse Gas (GHG) emissions that may be attributed to the transportation phase and refining phase for the metalloid antimony that is proposed to be extracted from the Stibnite Mine in Idaho, USA by Perpetua Resources. The following report describes the processes undertaken by Evergreen International to determine the total emissions associated with transporting and refining 44,000 metric tons of antimony (Table 4 provides a summary of these findings).

The boundary of this analysis begins in Cascade, ID when the antimony concentrate reaches HWY 55. Perpetua Resources does preliminary transportation within the Operations Area Boundary, in the mined pits, and along the Burntlog Route as well as preliminary processing of the stibnite ore on site, including grinding, floating, and filtering. This analysis does not duplicate the emissions analysis provided by Perpetua Resources for on-site transportation and processing.

To determine feasible representatives for transportation and refining scenarios, guidance was taken from Perpetua's publicly available documentation. The website of Perpetua Resources website:

> *From technology and defense applications to grid capacity storage batteries, the critical mineral antimony is key to achieving a more sustainable and secure future. Yet, the United States has no domestically mined sources of antimony and China, Russia and Tajikistan control more than 90 percent of global production (USGS 2020). Dependance on these countries puts our supply chain, and our future at risk.*

In keeping with Perpetua's stated benefits of having domestically sourced antimony production for supply security, we considered the three destinations that would uphold the security considerations for refining. The three destinations are Strategic & Precious Metals LLC (SPMP) in Oman, United States Antimony S.A. de C.V. (USAMSA) in Mexico, and United States Antimony Corporation (USAC). It is important to note that Perpetua does not define the most likely refineries based upon this statement:

> *The concentrate, when sold, would likely be shipped to facilities outside of the United States for smelting and refining because there are currently no such facilities operating in the United States with capacity for refining antimony sulfide concentrate. There are United States companies with refining equipment facilities and expertise that could potentially be brought online at some future date to refine antimony sulfide concentrate; however, Perpetua Resources does not have contracts in place with these companies and their ability to handle these concentrates has not been determined.*

Table 1 Displays the equations and assumptions for determining GHG emissions related to the transportation of the antimony concentrate to the three refineries. Essentially, these variables can be condensed to the most likely modes of transportation, the distance, and total weight of the shipment. The total weight of 97,777 metric tons is based upon Perpetua's estimate of 44,000mt of antimony in addition to the 40-45% tonnage for the sulfur, water, and other minerals that will be removed during the refining process.

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Although it is difficult to determine the exact processes that will take place during refining due to a number of dynamic variables, including the concentration or grade of the antimony (Stamp et al., 2013). However, based on the disclosed concentrations and characteristics, it is likely that both SPMP and USAMSA would rely on a similar refining method (USAC, 2022; SPMP, 2022); the Pyrometallurgical Extraction of Antimony from Sulfide Concentrate would likely rely on Volatilization roasting in rotary kilns—Reduction smelting (Multani et al., 2016; Li et al., 2021; Moosavi et al., 2022). It is important to note that the USAC refinery in Montana is not a viable refinery as it is currently set up to receive antimony oxides (rather than sulfides) which are of a higher concentration and may utilize different processes (USAC, 2022; Moosavi et al., 2022).

A review was undertaken of corporate documents, peer-reviewed literature, and life cycle inventory databases to determine the most appropriate scope and processes to be included in calculating the GHG emissions related to the Pyrometallurgical Extraction of Antimony from Sulfide Concentrate. The key process for evaluation was volatilization roasting in rotary kilns, also known as reduction smelting. Other important variables included the weight of the concentrate, the sulfide component, the energy source of the refinery, cooling, and other smelting equipment and operations. As mentioned earlier, the on-site processing in Idaho was excluded from calculations.

The total global warming potential (GWP) for antimony refining that was determined by this evaluation was **24,600 metric tons of CO_2eq (558 kg CO2 per metric ton) at SPMP** in Oman and **24,300 metric tons of CO_2eq (552 kg CO2 per metric ton) at USAMSA** in Mexico. This GWP was calculated by modelling refinery processes in Simapro V9.1.0.8 a lifecycle assessment software that contains inventories data on emissions from many sectors. A cross-reference was undertaken based upon a comparative analysis of other non-ferrous extraction processes and the final results were determined to be within the range of peer-reviewed evaluations (Ghosh, Banerjee, & Ray, 2014). Table 2 includes the full set of life cycle impacts that were evaluated, broken out by the metric ton of antimony produced. If the metric tons of antimony change in future mining plans, the information in Table 2 can be used to update emissions estimates. Table 3 extrapolates that data for the full quantity of antimony proposed to be transported and refined. Finally, Table 4 summarizes the grand total of emissions for the two transport and refining scenarios.

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Table 1. Evaluation of GHG Emissions from Transportation to Antimony Refineries				
Processing Destination	**Transport Type**	**Distance from Stibnite Mine (Hwy 55 in Cascade ID)**	**GHG per metric ton shipped**	**Total GHG**
SPMP CJ94+8CC Falaz, Sohar 322, Oman	Truck[1] & Ship[2]	860 km + 19,000 km	957 kg CO_2eq	42,108 metric ton CO_2eq
USAMSA Madero smelter, Coahuila, Mexico	Truck[1] & Rail[3]	119 km + 2896 km	147 kg CO_2eq	6,494 metric ton CO_2eq
USAC* 47 Cox Gulch Rd, Thompson Falls, MT	Truck[1]	667 km	142 kg CO_2eq	6,248 metric ton CO_2eq
LCI References: [1] USLCI 2010, [2]USLCI 2007, [3]USLCI 2007 *Not considered a viable refinery location. The transportation weight: 97,777 metric tons				

Table 2. Declaration Of Environmental Indicators Derived From Lca Per Metric Ton Of Antimony Produced.						
Impact category	**Unit**	**Refinery/ Oman**	**Refinery/ Mexico**	**Shipping/ Oman**	**Shipping/ Mexico**	**Shipping/ MT**
Global warming	kg CO2 eq	558.0	552.4	957.3	147.6	142.0
Ozone depletion	kg CFC-11 eq	2.37E-05	7.85E-06	0	0	0.0
Eutrophication	kg N eq	1.5	1.9	1.0	0	0.1
Acidification	kg SO2 eq	32.9	33.2	18.4	2.6	1.9
Smog	kg O3 eq	7.9	11.0	531	85.8	48.2
Abiotic depletion non-fossil mineral	kg Sb eq	1.92E-06	1.87E-06	0	0	0
Abiotic depletion (fossil fuels)	MJ	3439.1	2976.7	12462.0	1902.9	2034.6
Renewable primary energy resources as energy	MJ	81.4	133.9	0	0	0
Renewable primary resources as material	MJ	0	0	0	0	0
Non-renewable primary resources as energy	MJ	4009.1	3545.2	12462.0	1902.9	2034.6
Non-renewable primary resources as material	MJ	0	0	0	0	0
Consumption of freshwater	m3	16.8	7.7	0	0	0

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Table 3. Declaration Of Environmental Indicators Derived From Lca For The Total 44,000 Metric Tons Of Antimony Proposed To Be Transported And Refined.						
Impact category	**Unit**	**Refinery/ SPMP**	**Refinery/ USAMSA**	**Shipping/ SPMP**	**Shipping/ USAMSA**	**Shipping/ MT**
Global warming	kg CO2 eq	2.46E+07	2.43E+07	4.21E+07	6.49E+06	6.25E+06
Ozone depletion	kg CFC-11 eq	1.04	3.45E-01	0	0	0
Eutrophication	kg N eq	6.60E+04	8.36E+04	4.40E+04	0.00E+00	4.40E+03
Acidification	kg SO2 eq	1.45E+06	1.46E+06	8.10E+05	1.14E+05	8.36E+04
Smog	kg O3 eq	3.48E+05	4.84E+05	2.34E+07	3.78E+06	2.12E+06
Abiotic depletion non-fossil mineral	kg Sb eq	8.45E-02	8.23E-02	0	0	0
Abiotic depletion (fossil fuels)	MJ	1.51E+08	1.31E+08	5.48E+08	8.37E+07	8.95E+07
Renewable primary energy resources as energy	MJ	3.58E+06	5.89E+06	0	0	0
Renewable primary resources as material	MJ	0	0	0	0	0
Non-renewable primary resources as energy	MJ	1.76E+08	1.56E+08	5.48E+08	8.37E+07	8.95E+07
Non-renewable primary resources as material	MJ	0	0	0	0	0
Consumption of freshwater	m3	7.39E+05	3.39E+05	0	0	0

Table 4. Summary Of Total Emissions From Alternative Transport And Refining Scenarios For Total Proposed 44,000 Metric Tons Of Antimony.			
	Total Transport Emissions	Total Refining Emissions	**Final Total Emissions**
SPMP	42,108 metric tons CO_2eq	24,600 metric tons CO_2eq	**66,708 metric tons CO_2eq**
USAMSA	6,494 metric tons CO_2eq	24,300 metric tons CO_2eq	**30,794 metric tons CO_2eq**

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