LIFE CYCLE DATA

EXECUTIVE SUMMARY

28
Ni
Nickel

The following study conducted by PE International calculates the global average primary energy demand and environmental impacts of nickel metal and ferronickel production. The study was commissioned by the Nickel Institute in 2012. It is based on data provided by in total 19 production sites from nine nickel producing companies. Production sites from Australia, Brazil, Canada, Columbia, Dominican Republic, Finland, France, Japan, New Caledonia, Norway, Russia, Venezuela and United Kingdom provided data for the study.

The study is based on data from companies for the reference year 2011 (with data from 2010 provided by one company). It is an update of existing LCI data from 1999 which were published in 2003 and which can be downloaded from the NI website.

As a result of the wider regional and market coverage, the data are more representative than the previous data. Changes in process technology, the inclusion of new mining projects as well as the inclusion of all major nickel producers outside of China are reflected in the data.

The main user of ferronickel and nickel metal is the stainless steel industry. Other downstream users of nickel metal as well as the scientific community will also have an interest in the recent life cycle data. The data can be used by Nickel Institute member companies to benchmark their company specific data against the global average.

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GOAL

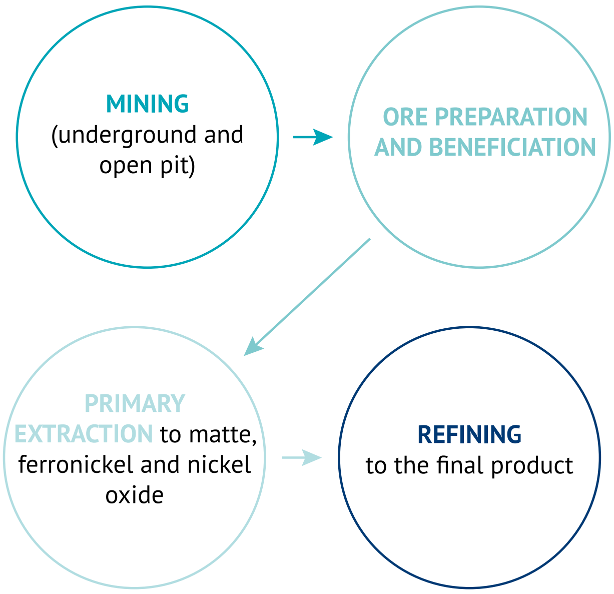
The aim of the study is to provide environmental impact data for two products of the nickel industry, using current and robust data of nickel production. The products are nickel metal (class 1) and ferronickel. All processes from raw materials extraction to beneficiation to smelting and refining are investigated up to the final product ("from cradle to gate").

The project aims to provide life cycle inventory data to downstream users of nickel and ferronickel such as the stainless steel industry. In addition, this study includes a range of benchmark analyses designed to assist the nickel industry and its members to better analyze, improve and communicate their environmental performance.

Besides the Nickel Institute, its member companies and the stainless steel industry, the intended audience for the report comprises regulators/policy makers, customers, academia, LCA practitioners and civil society.

SCOPE

The scope includes studying all of the routes of production of nickel metal and ferronickel, for both sulphidic and laterite ores. It comprises mining, ore preparation, primary extraction and refining.



Within the scope, the system function is the production of the two nickel products investigated: nickel metal (100% Ni content) and ferronickel (29% Ni content). The two products are evaluated separately. Therefore a functional unit is defined for each nickel product. The functional unit, which enables the system inputs/outputs to be quantified and normalized, is 1 kg of nickel contained in the nickel product at the factory gate.

SYSTEM BOUNDARIES

The study is a "cradle-to-gate" LCA study. It covers all production steps from raw materials "in the earth" (i.e. the cradle) to finished products ready to be shipped from the factories (i.e. the gate). It does not include the manufacture of downstream products, their use, end of life, and scrap recovery schemes. This is a proper choice of the system boundaries, because the nickel products serve as intermediates that enter many different product life cycles. Transport was not included into the scope of the study.

The nickel industry is different from other metal industries. Various production routes are applied to create nickel products. All nickel products analyzed undergo ore mining as the first production step. The ore is the further processed in either ore beneficiation (sulphidic ore) or ore preparation (oxidic ore) and in the following a "primary extraction" step, which could involve smelting, leaching, calcining and other processes. Ferronickel is produced during the primary extraction step. The further refining step produces class 1 nickel.

Secondary production, or a production route by recycling, is not considered in this study since most recovery of nickel occurs in its alloy state, combined with other metals. As an example, the bulk of recycled nickel is in steel, and is not separated to nickel only.

Nickel production also generates metallic by-products, such as Cu, Co or PGM´s. In addition, certain non-metal co-products occur, such as sulphuric acid, which is recovered during the primary extraction of sulphidic ores.

Table 1 - Technologies covered in the study	
Primary extraction	**Refining**
DON flash (Direct Nickel Flash) smelting	Ammonia PAL (phenylalanine ammonia-lyase) - H reduction
EAF (Electric Arc Furnace)	Chloride and sulphide electrowinning
HPAL (High Pressure Acid Leach)	Hydrosulphidic refining
Flash Furnace	Pyro-refining
	Natural gas reforming
	Volatisation
	Leaching (bio/acid)

Table 2 - LCI results		
Impact category	**1 kg nickel (class 1)**	**1 kg Ni in Feni**
Primary Energy Demand [MJ]	149	508
Global Warming Potential [kg CO2-Equiv.]	7.87	32
Acidification Potential [kg SO2-Equiv.]	1.46	0.17
Eutrophication Potential [kg phosphate-Equiv.]	0.0042	0.011
Photochemical Ozone Creation Potential [kg ethene-Equiv.]	0.059	0.011

GEOGRAPHIC & TECHNOLOGY COVERAGE

The study covers data from companies and sites in North America, South America, Australia, Europe and Russia. Those countries and regions represent 56% of world nickel production, and 40% of world ferronickel production.

The investigated nickel products can be produced through a number of routes, using a range of technologies and inputs. The technology covered in the study includes underground and open pit mining, and the processing of both oxidic and sulphidic ores through pyrometallurgical and hydrometallurgical techniques. The technologies are described in the table 1.

BY-PRODUCTS

The treatment of by-products is a key methodological issue for most LCA studies. In the case of nickel it is of high relevance due to the various by-products yielded during nickel production, such as platinum group metals, cobalt, copper, iron oxide, sulfuric acid and steam.

Allocation was applied in accordance with the ISO 14044 standard. For metallic by-products, economic allocation was applied. For the metallic by-products, an average market price over the past 15 years was determined. As part of the sensitivity analysis, the market prices for 2010 and 2011 were applied to the metallic by-products. For non-metallic by-products such as sulphuric acid, system expansion was applied. The relevant impacts (and resulting credits) for sulphuric acid production were determined by using the sulfuric acid dataset from the GaBi 5 databases.

Maybe the following could be used:

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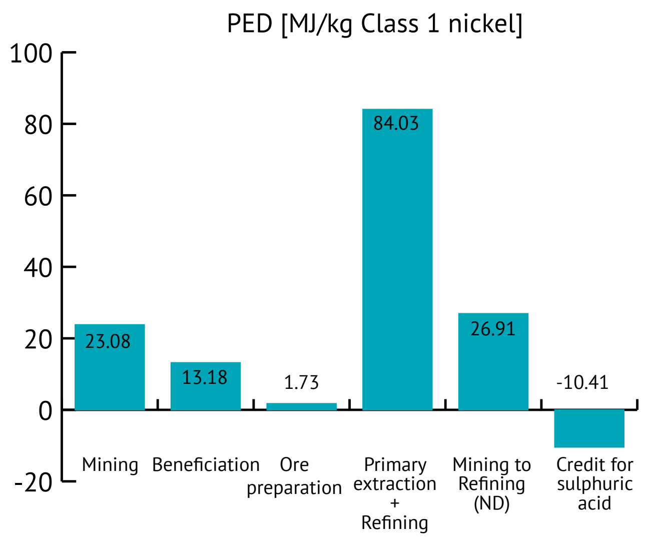
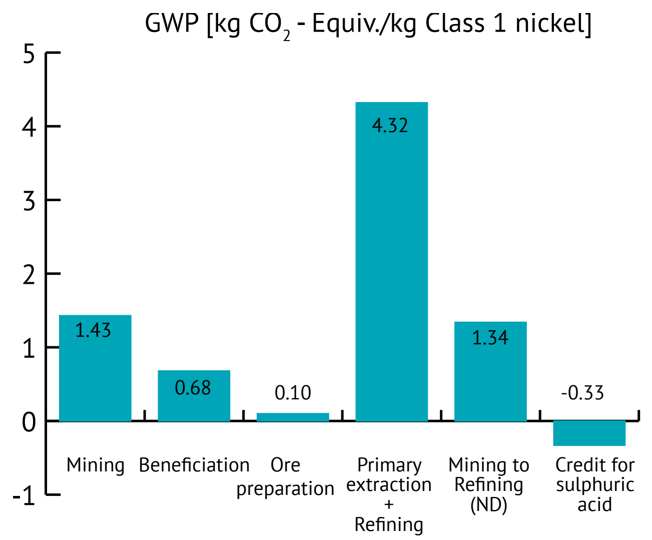
Graph 1: Distribution of Primary Energy Demand (PED) for nickel metal over process stages



Graph 2: Distribution of Global Warming Potential (GWP) for nickel metal over process stages



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LCI RESULTS

The LCI results are shown for 1kg of nickel metal content for the both investigated products: nickel metal class 1 and ferronickel. The most relevant investigated impact categories were investigated. The table 2 provides an overview on the results for nickel metal class 1 and ferronickel (please note that the results are shown per kg of Ni metal content).

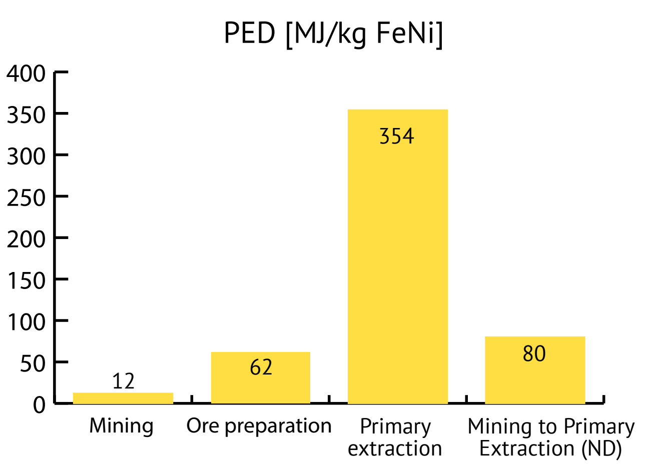
For Primary Energy Demand and Global Warming Potential as most relevant impact categories, the results in Graph 1 and 2 are shown relative to the production process for nickel metal and ferronickel.

For nickel metal (Graph 3 and 4), the stages of primary extraction and refining are the main contributor to the PED as well as the GWP. These steps account for more than 55% of the total GWP and PED. Besides the emissions associated with onsite combustion, fuels and electricity use, emissions attributed to upstream materials also makes up a large proportion of PED and GWP.

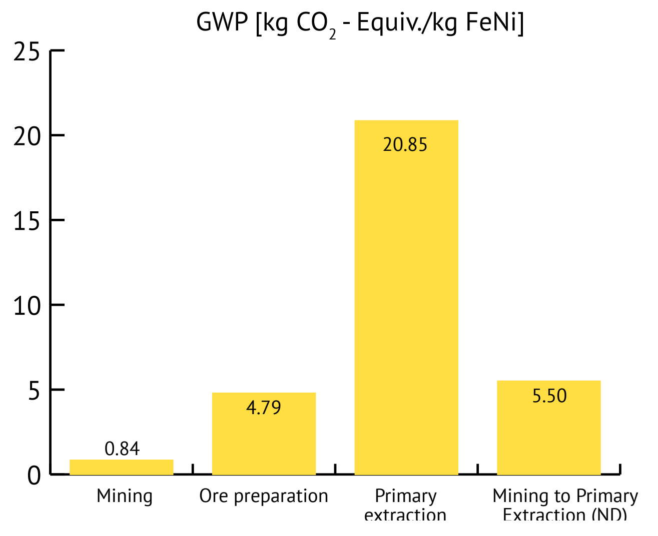
The total primary energy demand for the cradle-to-gate life cycle of 1 kg of Ferronickel is 147 MJ. With a nickel content of 29%, the primary energy demand for 1 kg nickel in Ferronickel is 508 MJ. This is significantly higher than that of Nickel (Class 1) owing primarily to the use of laterite based ore. Extraction of nickel from laterite ore is more energy intensive than from sulphidic ore. Primary extraction accounts for 60% of energy demand.

The global warming potential (GWP) of 1 kg ferronickel is 9.28 kg CO2-equivalent. For 1 kg nickel in ferronickel this value is 32 kg CO2-equivalent. As shown in the graphs, this is primarily due to electricity consumption in primary extraction. Primary extraction contributes 65% to global warming, of which 63% is attributed to electricity consumption. Onsite emissions result from combustion of hard coal and other reducing agents.

Graph 3: Distribution of Primary Energy Demand (PED) for Ferronickel over process stages



Graph 4: Distribution of Global Warming Potential (GWP) for ferronickel



REVIEW

The update of the nickel and ferronickel LCI update was accompanied by a critical review as recommended in ISO 14044. The aim of the critical review was to ensure consistency with the standard, to ensure technical and scientific validity of the methods as well as transparency and consistency of the report. The critical review was conducted by Prof. Matthias Finkbeiner from Technical University of Berlin as independent expert reviewer.

Moreover, the data collection process and data aggregation was accompanied by an independent industry expert, ensuring consistency in the data collection and provision of companies.

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