**Supplementary Information**

**Identifying supply risks by mapping the cobalt supply chain**

Susan van den Brink, René Kleijn, Benjamin Sprecher, Arnold Tukker

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# Trade Flow Inconsistencies

This section provides additional information about the trade flow analysis in section 3.3. Sun et al. (2019) made a similar map of the cobalt trade. The map of cobalt trade (based on 2015) from the study by Sun et al. (2019) shows flows of cobalt ores and concentrates between the Democratic Republic of the Congo and Finland, and Belgium. Their study is based on export data, but they noted that export trade flows of Democratic Republic of the Congo were not reported in the Trade Database, and that the trade amount from the Democratic Republic of the Congo was estimated by corresponding trade of other countries (Sun et al., 2019). In our study, based on import data, we did find export flows from the Democratic Republic of Congo, but not between the Democratic Republic of the Congo and Belgium and Finland, therefore these are not shown in Figure 2. The BGS (2018) notes that the cobalt recorded as refined in Belgium is actually refined in China, which would explain the lack of flows between Belgium and the Democratic Republic of the Congo. An explanation for the lack of flows to Finland could be that the import of these countries is reported under a commodity code that is not specifically for cobalt, e.g. under nickel or copper products. The latter would also explain the export flows missing from Indonesia, Vietnam and the Philippines, these countries mine cobalt, do not have a refinery and export little to no cobalt.

Table S1: The estimations of cobalt content in the cobalt intermediate products trade flows (Comtrade, 2019)

The cobalt content of cobalt ores can range from 0.1% to 2.5% depending on the deposit (BGS, 2009), while cobalt concentrates can contain up to 15% of cobalt content (Young, Campbell and Taylor, 2017). Cobalt mattes can contain 1.5% cobalt (BGS, 2009), while cobalt powders can contain 99.9% cobalt (International Agency for Research on Cancer, 2018), see table 3.

|  |  |
| --- | --- |
| **HS code** | **Description** |
| **2605** | Cobalt ores and concentrates |
| **2822** | Cobalt Oxides and hydroxides: commercial cobalt oxides |
| **8105** | Cobalt: mattes and other intermediate products of cobalt metallurgy, cobalt and articles thereof, including waste and scrap |
| **282734** | Chlorides: of cobalt |
| **291523** | Acids: saturated acyclic monocarboxylic acids: cobalt acetates: no results import of export data |

|  |  |  |  |
| --- | --- | --- | --- |
| **Cobalt ‘product’** | **HS code** | **Estimated percentage cobalt** | **Source** |
| Cobalt ores | 2605 | **0.1% to 2.5%** depending on the deposit | British Geological Survey (2009). Cobalt. <https://www.bgs.ac.uk/downloads/start.cfm?id=1400> (accessed 16 April 2019) |
| Cobalt concentrates | 2605 | **Up to 15%** | Young, R.S., Campbell Taylor, J. (2017) Cobalt processing. <https://www.britannica.com/technology/cobalt-processing> (accessed 16 April 2019) |
| Cobalt oxides | 2822 | **Around 79%** (depending on form) | Wikipedia (2019). Cobalt (II) oxide. <https://en.wikipedia.org/wiki/Cobalt(II)_oxide> (accessed 16 April 2019) |
| Cobalt hydroxide | 2822 | **Around 54%** (depending on form) | Wikipedia (2019). Cobalt (II) hydroxide. <https://en.wikipedia.org/wiki/Cobalt(II)_hydroxide> |
| Unwrought cobalt | 8105 | For example an ingot of unwrought cobalt alloy is made up of **68%** cobalt. Bare hardfacing welding rots typically contain **60%** of cobalt. Electric induction melted **64%.** | Tariff Nomenclature (2016). Other cobalt, unwrought, powders. <https://tariff.cc/en/other-cobalt-unwrought-powders> (accessed 16 April 2019) |
| Powders | 8105 | Commercial cobalt-metal powders are available in purities ranging from **99% to ≥ 99.999%** in many grades, particle size ranges and forms. | International Agency for Research on Cancer. (2018). Metallic cobalt particles (with or without tungsten carbide). <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono86-6.pdf> (accessed 16 April 2019) |
| Cobalt matte | 8105 | Cobalt content in matte is around **1.5% to 2%.** | British Geological Survey (2009). Cobalt. <https://www.bgs.ac.uk/downloads/start.cfm?id=1400> (accessed 16 April 2019) |

Table S2: Mined and refined cobalt production (metal content) in kiloton (kt) in 2016 (BGS, 2018)

|  |  |  |
| --- | --- | --- |
| **Country** | **Mined cobalt production 2016 (kt)\*** | **Refined cobalt production 2016 (kt)\*\*** |
| **Democratic Republic of the Congo** | 69 | 0 |
| **China** | 11 | 45 |
| **Canada** | 7 | 6 |
| **Australia** | 6 | 3 |
| **Zambia** | 5 | 5 |
| **New Caledonia** | 4 | 3 |
| **Cuba** | 4 | 0 |
| **Brazil** | 4 | 0 |
| **Madagascar** | 3 | 3 |
| **Philippines** | 3 | 0 |
| **Finland** | 2 | 12 |
| **Papua New Guinea** | 2 | 0 |
| **Russia** | 2 | 2 |
| **Morocco** | 2 | 2 |
| **Poland** | 2 | 0 |
| **South Africa** | 1 | 1 |
| **United States** | 1 | 0 |
| **Zimbabwe** | 0 | 0 |
| **Indonesia** | 0 | 0 |
| **Botswana** | 0 | 0 |
| **Vietnam** | 0 | 0 |
| **Belgium** |  | 6 |
| **Japan** |  | 4 |
| **Norway** |  | 4 |
| **France** |  | 0 |
| **India** |  | 0 |
| **Total** | **128** | **98** |

\*Mined cobalt production: the production for the United States, Brazil, China and Indonesia are not provided by the countries but based on estimations by the BGS. For Russia, Morocco, South Africa, Zambia and Zimbabwe the cobalt is either metal and/or refined.

\*\*Refined cobalt production: refined cobalt can be in the form of metal, oxides, carbonates, sulfates and many other compounds, efforts are made to avoid double-counting but it is not always possible to be certain (BGS, 2018)

Table S3. Overview of cobalt mines globally

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Country** | **Total cobalt production country 2016** | **Mine Sites** | **Cobalt by-product** | **Cobalt Production (t) 2016\*** | **Operator** | **Shareholder(s)** | **References\*** |
| **Australia** | **6012** | [Ravensthorpe (Bandalup)](http://www.first-quantum.com/) | Nickel | **920** | First Quantum Minerals | First Quantum Minerals | Indian Bureau of Mines (2017), Australian Mining (2018). |
| [Maggie Hays (Lake Johnston - Norilsk)](http://www.lionore.com/) | Nickel |  | LionOre Australia | LionOre Australia Pty Ltd | Australian Mining (2018) |
| Maggie Hays (Lake Johnston - Norilsk) | Nickel |  | Norilsk Nickel | Norilsk Nickel | Australian Mining (2018) |
| Mariners | Nickel |  | Mincor Resources | Mincor Resources | Australian Mining (2018) |
| McLeay (Victor South, Victor) | Nickel |  | Independence Group | Independence Group | Australian Mining (2018) |
| Cliffs (Cliffs Nickel, Mt Keith Cliffs Charterhall) | Nickel |  | BHP Biliton | BHP Biliton | Australian Mining (2018) |
| Tapinos | Nickel |  | Jubilee Metals Group | Jubilee Metals Group | Australian Mining (2018) |
| Tritton | Copper |  | Aeris Resources | Aeris Resources | Australian Mining (2018) |
| Lounge Lizard Nickel | Nickel |  | Western Areas | Western Areas | Australian Mining (2018) |
| Miitel | Nickel |  | Mincor Resources | Mincor Resources | Australian Mining (2018) |
| Murrin Murrin | Nickel | **2800** | Minara Resources | Glencore | Australian Mining (2018), Glencore (2016) |
| Mount Keith | Nickel |  | BHP Biliton | BHP Biliton | Australian Mining (2018) |
| Savannah | Nickel | **476** | Panoramic Resources | Zeta Resources | USGS (2017b) |
| Greenville/Townsville, Queensland | Nickel | **1850** | Queensland Nickel Group | Queensland Nickel Group | USGS (2017b) |
| **Botswana** | **248** | Selebi-Phikwe Mines | Nickel | **400** | Bamangwato Concessions | Government Botswana (94%, Norilsk Nickel 6%) | USGS (2017c), BGR Data (2019) |
| **Brazil** | **3600** | Sante Fe | Nickel |  | Santa Fe Gold Corporation | Santa Fe Gold Corporation | Santa Fe Gold Corporation (2018), USGS (2017a) |
| Serra do Tapa | Nickel |  | Horizonte Minerals Plc | Glencore | USGS (2017a), Newswire (2016) |
| Vale dos Sonhos (Araguaia) | Nickel |  | Horizonte Minerals Plc | Glencore | USGS (2017a), Catalogo de Mineracao Brasil (2017) |
| Vermelho | Nickel | **2500** | Horizonte Minerals Plc | Glencore | USGS (2017a), USGS (2017b), Horizonte Minerals (2018) |
| Vila Oito | Nickel |  | Horizonte Minerals Plc | Glencore | USGS (2017a), Lara Exploration (2007) |
| Fortaleza de Minas | Nickel |  | Votorantim | Votorantim Group | USGS (2017a), Wikipedia (2018), BGR Data (2019) |
| Niquelandia, Goias | Nickel |  | Votorantim | Votorantim Group | BGR Data (2019) |
| Santa Rita, Chino Mine | Copper |  | Freeport McMoran | Freeport McMoran | Freeport-McMoran (2018), Indian Bureau of Mines (2017), USGS (2017b) |
| Sao Miguel Paulista | Nickel |  | Votorantim | Votorantim | USGS (2017b) |
| Jacare | Nickel |  | Anglo American | Anglo American | Mining Atlas (2018b) |
| Americano do Brasil, Goias |  |  | Prometalica | Prometalica |  |
| **Canada** | **6969** | Voisey’s Bay | Nickel | **887** | Vale | Vale | Vale (2016), BGR Data (2019) |
| Raglan | Nickel | **1000** | Glencore | Glencore | Natural Resources Canada (2018), BGR Data (2019) |
| Sudbury | Nickel | **882** | Vale Canada Limited | Vale | Natural Resources Canada (2018), BGR Data (2019) |
| Nunavik | Nickel |  | Canadian Royalties Inc. | Canadian Royalties Inc. | Natural Resources Canada (2018), BGR Data (2019) |
| Nickel Rim South, Fraser | Nickel | **100** | Glencore Canada Corporation | Glencore | Natural Resources Canada (2018), BGR Data (2019) |
| Garson | Nickel |  | Vale Canada Limited | Vale | Natural Resources Canada (2018), BGR Data (2019) |
| Stobie | Nickel |  | Vale Canada Limited | Vale | Natural Resources Canada (2018), BGR Data (2019) |
| Clarabelle | Nickel |  | Vale Canada Limited | Vale | Natural Resources Canada (2018), BGR Data (2019) |
| Copper Cliff North | Nickel | **606** | Vale Canada Limited | Vale | Natural Resources Canada (2018), BGR Data (2019), Ontario Prospectors Association (2016) |
| Creighton | Nickel |  | Vale Canada Limited | Vale | Natural Resources Canada (2018), BGR Data (2019) |
| Coleman/McCreedy East | Nickel |  | Vale Canada Limited | Vale | Natural Resources Canada (2018), BGR Data (2019) |
| Strathcona | Nickel |  | Glencore Canada Corporation | Glencore | Natural Resources Canada (2018), BGR Data (2019) |
| Totten | Nickel |  | Vale Canada Limited | Vale | Natural Resources Canada (2018), BGR Data (2019) |
| Thompson | Nickel | **700** | Vale Canada Limited | Vale | Natural Resources Canada (2018), BGR Data (2019) |
| Birchtree | Nickel |  | Vale Canada Limited | Vale | Natural Resources Canada (2018), BGR Data (2019) |
| Lac des Iles | Nickel |  | North American Palladium | North American Palladium | BGR Data (2019) |
| Rainy River | Nickel |  | New Gold Inc | New Gold Inc | BGR Data (2019) |
| **China** | **10500** | Tangdan (Dongchuan) | Copper |  |  |  | USGS (2017a) |
| Jinchuan | Nickel |  |  |  | USGS (2017a) |
| Yangliuping | Nickel |  |  |  | USGS (2017a) |
| Lala (Lalachang) | Copper |  |  |  | USGS (2017a) |
| Longshou | Nickel |  | Jinchuan Group | Jinchuan Group | BGR Data (2019) |
| Deerni | Copper |  | Zijin Mining | Zijin Mining | BGR Data (2019) |
| **Cuba** | **3694** | Moa Nickel S.A. (mine and processing plant) | Nickel | **3694** | Sherritt International | Government of Cuba (50%), Sherritt International (50%) | Investing News (2018), Sheritt International (2017:p19),USGS (2017a), BGR Data (2019), Brown: Sherritt reported only 50% of the total production |
| Pinares de Mayari | Nickel |  | General Nickel Company S.A. | General Nickel Company S.A. (65%), BHP Biliton (35%) | The Diggins (2018), USGS (2017a) |
| Punta Gorda | Nickel |  | Sherritt International | Sherritt International | Investor Intel (2014), Sheritt International (2017:p19) |
| **Democratic Republic of the Congo** | **68822** | Deziwa | Copper |  | Société Minière de Deziwa et Ecaille C | Gecamines | CongoMines (2018), USGS (2017a) |
| Ecaille C | Copper |  | Zijin Mining Group Co. | Zijin Mining Group Co. Ltd | USGS (2017a) |
| Dilala East | Copper |  | Compagnie Minière de Dilala | Gecamines | CongoMines (2018) |
| DIMA (Mashamba Est, Mashamba West, Dikuluwe) | Copper |  | Katanga Mining | Glencore | CongoMines (2018) |
| Usoke production plant | Copper | **2400** | Chemaf | Chemaf | Congomines.org, USGS (2017a), Chemaf (2018) |
| Etoile, Etoile HMS 1, Etoile HMS 2 | Copper | **3800** | Shalina Resources Ltd | Chemaf | CongoMines (2018), USGS (2017a), BGR (2017) |
| Ruashi Mine | Copper | **3264** | Metorex | Jinchuan Group | Chemaf (2018), CongoMines (2018), USGS (2017a) |
| Kababankola | Copper |  | Kababankola Mining Company | Gecamines | CongoMines (2018) |
| Kabolela, Kipese | Copper |  | Société Minière de Kabolela et de Kipese (SMKK) | Eurasian Natural Resources Corporation (50%), Groupe Fleurette (50%) | CongoMines (2018), USGS (2017a) |
| Kakanda, Lwita Est, Mukondo Mountain | Copper | **5100** | Boss mining | Eurasian Natural Resources Corporation | CongoMines (2018), USGS (2017a), Eurasian Natural Resources Corporation (2017) |
| Kii | Copper |  | Congolaise des Mines et du Développement (COMIDE) | Eurasian Natural Resources Corporation | CongoMines (2018), USGS (2017a) |
| Kalakundi | Copper |  | Société d'exploitation des Gisements de Kalukundi(Swanmines) | Gecamines (50%), Eurasian (25%), Africo Resources (25%) | CongoMines (2018), USGS (2017a) |
| Kambove, Kamoya | Copper |  | Compagnie Minière de Kambove (COMIKA) | Wanbao Mining | CongoMines (2018), USGS (2017a) |
| Kamfundwa | Copper |  | Gecamines | Gecamines | Mindat (2018a), CongoMines (2018), Wikipedia (2018b) |
| Musonoi | Copper |  | Compagnie Minière de Musonoi (COMMUS) | Gecamines (28%), Jinchuan Group (72%) | CongoMines (2018), USGS (2017a) |
| Kamoto, Kananga, KOV, Mashamba Est, T17, Tilwezembe | Copper | **2901** | Katanga Mining Limited | Glencore | CongoMines (2018), USGS (2017a), BGR (2017) |
| Kipapila, Kimpe, Mayaba | Copper |  | Société de Dévéloppement Industriel et Minier du Katanga(Sodimika) | Gecamines | Mindat (2018b), CongoMines (2018) |
| Kipoi Central, Kipoi North | Copper |  | Société d'exploitation de Kipoi (SEK) | Tiger Resources | CongoMines (2018), USGS (2017a) |
| Kisanfu | Copper |  | Phelps Dodge Congo | Freeport Mc Moran Copper | CongoMines (2018), USGS (2017a) |
| Luishia | Copper | **480** | Miniere du Sud Katanga (CMSK) | Entreprise General Malta Forrest (60%), Gecamines (40%) | CongoMines (2018), USGS (2017a) |
| Luiswishi | Copper | **6200** | Huayou Cobalt (previously Congo Dongfang International Mining (CDM)) | Huayou Cobalt | CongoMines (2018), USGS (2017a), BGR (2017) |
| Mutanda North (ex-Kansuki), Mutanda South, | Copper | **24500** | Mutanda ya Mukonkota Mining (MUMI) | Glencore | CongoMines (2018), USGS (2017a), Glencore (2016) |
| Mutoshi | Copper |  | Société Minière de Kolwezi (SMK) | Gecamines | CongoMines (2018), USGS (2017a) |
| Tenke Fungurume: Fwaulu, Fungurume, Kansalawile, Kwatebala, Mambilima, Mwadinkomba, and Tenke. | Copper | **16053** | Tenke Fungurume Mining (TFM) | China Molybdenum (56%, bought it from Freeport Mc Moran) Lundin Mining (24%) reported 16,053 tonnes of cobalt in 2016, Gecamines (20%) | CongoMines (2018), USGS (2017a), Lundin Mining (2017) |
| **Finland** | **2308** | Hitura | Nickel |  | Belvedere Mining Oy | Belvedere Resources Ltd | PWC (2012), USGS (2017a), Mining Atlas (2018) |
| Kevitsa | **Copper** | **420** | **Boliden** | **Boliden** | Boliden (2017), USGS (2017a), USGS (2017b), BGR Data (2019) |
| Kylylathi | **Copper** |  | Boliden (previous Kylylahti Copper Oy) | Boliden | Boliden (2017), USGS (2017a) |
| Sotkamo (formerly Talvivaara) | Nickel | **20** | Terrafame Mining | Trafigura and Solidium | USGS (2017a), Yle (2018), Talvivaara Mining Company Plc (2013), BGR Data (2019) |
| Haarakumpu | Copper |  | Belvedere Mining Oy | Belvedere Resources Ltd | USGS (2017a), USGS (2017b) |
| Kouvervaara | Copper |  | Belvedere Mining Oy | Belvedere Resources Ltd | PWC (2012), USGS (2017a) |
| Outokumpu | Copper |  | Outokumpu Oyj/Boliden Kylylahti Copper Oy | Altona mining/ Copper Mountain Mining Corporation | USGS (2017a) |
| Outokumpu (Luikonlahti) | Copper |  | Outokumpu Oyj/Boliden Kylylahti Copper Oy | Altona mining/ Copper Mountain Mining Corporation | USGS (2017a) |
| Outokumpu (Saramäki) | Copper |  | Outokumpu Oyj/Boliden Kylylahti Copper Oy | Altona mining/ Copper Mountain Mining Corporation | USGS (2017a) |
| Outokumpu (Vuonos) | Copper |  | Outokumpu Oyj/Boliden Kylylahti Copper Oy | Altona mining/ Copper Mountain Mining Corporation | USGS (2017a) |
| Harjavalta | Nickel |  | Norilsk Nickel | Norilsk Nickel | The Balance (2018), USGS (2017a) |
| **Indonesia** | **350** | Halmahera/Weda Bay | Nickel | **400** | Eramet | PT Antam (90%), Mitsibushi (10%) | Eramet (2010), USGS (2017a) |
| La Sampala | Nickel |  | Rio Tinto | Rio Tinto | DowntoEarth (2006), USGS (2017a) |
| Sorowako (Sulawesi) | Nickel |  | Vale Indonesia |  | USGS (2017a), USGS (2017b) |
| Pomalaa, Tanjung Buli, Tapunopaka | Nickel |  | PT Antam | PT Antam |  |
| **Madagascar** | **3370** | Ambatovy | Nickel | **1309** | Sherritt International | Sherritt International | Sherritt International (2017:p19), Wikipedia (2018c), USGS (2017a), BGR Data (2019) |
| **Morocco** | **2081** | Bou Azzer | Cobalt | **2081** | Compagnie de Tifnout Tiranimine (CTT) | Managem Group | USGS (2017a), Managem Group (2016) |
| **New Caledonia** | **4350** | Goro (VNC) | Nickel | **3188** | Goro (VNC) | Vale | USGS (2017a), Vale (2016), BGR Data (2019) |
|  |  | Koniambo | Nickel |  | Koniambo Nickel Sas | Glencore (49%), Societe Miniere du Sud Pacifique (51%) | Glencore (2016), Vale (2016), USGS (2017a) |
| **Papua New Guinea** | **2191** | Ramu | Nickel | **2191** | Highlands Pacific | China Metallurgical Group Corporation (75%), PNG Government (25%) | China Nonferrous Mining Corporation Limited (2016), BGR Data (2019) |
|  |  | Wowo Gap | Nickel |  | Niugini Nickel Ltd | Resource Mining Corporation Limited | USGS (2017a), Resource Mining Corporation Limited (2016) |
| **Philippines** | **2554** | Acoje/Zambalas | Nickel |  | Benguetcorp Nickel Mines Inc. | Benguetcorp Nickel Mines Inc. | Government of the Philippines (2018), USGS (2017a) |
|  | Agata/Bolobolo Karihatag | Nickel |  | Agata Mining Ventures | Agata Processing Inc | Government of the Philippines (2018), USGS (2017a) |
|  | Berong | Nickel |  | Berong Nickel Corporation | Berong Nickel Corporation | Government of the Philippines (2018), USGS (2017a) |
|  | Cagdianao, Hinatuan | Nickel |  | Cagdianao Mining Corporation | Nickel Asia Corp. | Government of the Philippines (2018), USGS (2017a), BGR Data (2019) |
|  | Ipilan | Nickel |  | Ipilan Nickel Corp | Ipilan Nickel Corp | Government of the Philippines (2018), USGS (2017a) |
|  | Mindoro | Nickel |  | Mindoro Resources Ltd | Mindoro Resources Ltd | Government of the Philippines (2018), USGS (2017a) |
|  | Nonoc | Nickel |  | Philnico Industrial Corp | Philnico Industrial Corp | Government of the Philippines (2018), USGS (2017a) |
|  | Rio Tuba Nickel mine and Rio Tuba Processing Plant, Coral bay Nickel Corporation and Taganito | Nickel | **2600** | Rio Tuba Nickel Mining Corporation/ Coral Bay Nickel Corporation | Nickel Asia | Government of the Philippines (2018), USGS (2017a), Coral Bay Nickel Corporation (2018), BGR Data (2019) |
|  | Taganaan | Nickel |  | Hinatuan Mining Corporation | Nickel Asia | Government of the Philippines (2018), USGS (2017a) |
|  | Taganito/Adlay | Nickel |  | Taganito Mining Corporation | Nickel Asia (65%), Pacific Metals (33.5%), Sojitz Phillipines (1.5%) | MetalBulletin (2015), USGS (2017a), Government of the Philippines (2018), BGR Data (2019) |
| **Poland** | **1670** | [Lubin-Malomice](https://en.wikipedia.org/wiki/Myszk%C3%B3w_mine) | Copper |  | [KGHM Polska](https://en.wikipedia.org/w/index.php?title=Strzelecki_Metals&action=edit&redlink=1) | KGHM | Wikipedia (2018d), KGHM (2019), BGR Data (2019) |
| **Russia** | **2100** | TAIMYR PENINSULA: Talnakhskoye, Oktyabrskoye Fields | Copper | **2040** | Norilsk Nickel | Norilsk Nickel | Investor Intel (2016) |
|  | Kola Peninsula: Tans-Baikal | Nickel |  | **Norilsk Nickel (Kola mining and metallurgical company)** | Norilsk Nickel (Kola mining and metallurgical company) | Investor Intel (2016), BGR Data (2019) |
|  | Ufaleynickel | Nickel |  | Ufaleynickel | Ufaleynickel | Investor Intel (2016) |
|  | YozhUralsnickel | Nickel |  | Yozhuralsnickel | Yozhuralsnickel | Investor Intel (2016) |
| **South Africa** | **1101** | Nkomati | Nickel | **1065** | Africa Rainbow Minerals | Norilsk Nickel Africa (50%), Africa Rainbow Minerals (50%) | BGR Data (2019) |
| **United States** | **690** | Eagle | Nickel | **650** | Eagle Nickel-Copper Mining | Lundin Mining |  |
| **Vietnam** | **134** | Ban Phuc nickel mine and plant, Tha Koa concession | Nickel | **277** | Asian Mineral Resources Limited (AMR) | Asian Mineral Resources | BGR Data (2019) |
| **Zambia** | **4725** | Baluba center Copper mine | Copper |  | China Nonferrous Mining Corporation Luanshya Copper mines | China Non-ferrous Mining (80%), ZZCM Investment (20%) |  |
|  | Chambishi | Copper | **2997** | Chambishi Metals plc Zambia | China Non-ferrous Mining (85%), ZCCM Investment (15%) | BGR Data (2019) |
|  | Chibuluma | Copper |  | Metorex | Metorex Pty Ltd (85%), ZZCM Investments (15%) |  |
|  | Nchanga, Konkola | Copper | **1700** | Konkola Copper Cobalt Operation | Vedanta Resources (79%), ZCCM Investment (21%) | BGR Data (2019) |
|  | Lubambe copper mine | Copper |  | Lubambe copper mine | EMR Resources (80%), ZCCM Investments (20%) |  |
|  | Lumwana copper mine | Copper |  | Lumwana copper mine | Barrick Gold Corporation |  |
|  | Mopani | Copper |  | Mopani copper/cobalt operation | Glencore (73%), First Quantum Minerals (17%), ZCCM Investments (10%) | BGR Data (2019) |
|  | Muliashi copper operation | Copper |  | China Nonferrous Mining Corporation Limited | China Non-ferrous Mining Corp (80%), ZCCM Investments (20%) |  |
|  | Nkana | Copper |  |  | Glencore |  |
| **Zimbabwe** | **409** | Trojan Mine at Bindura and Shangani Mine | Nickel | **800** | Bindura Nickel Corporation Ltd. (Mwana Africa plc) | Bindura Nickel |  |
|  | Mimosa | Nickel | **88** | Impala Platinum Holdings Ltd | Aquarius Platinum (50%), Impala Platinum (50%) | BGR Data (2019) |

\* References can be found in the article and in table S6.

Table S4: World Governance Index – PV weighted to cobalt mined and refined production. World Governance Index (2019).

|  |  |  |  |
| --- | --- | --- | --- |
|  | Political Stability and Absence of Violence/Terrorism | Mined cobalt production 2016 (BGS 2018) | Refined cobalt production 2016 (BGS 2018) |
| Congo, Dem. Rep. | -2,23 | 68822 | 400 |
| Philippines | -1,38 | 2554 |  |
| Russian Federation | -0,95 | 2100 | 2100 |
| Zimbabwe | -0,62 | 409 |  |
| China | -0,5 | 10500 | 45046 |
| Papua New Guinea | -0,5 | 2191 |  |
| Brazil | -0,38 | 3600 | 400 |
| Indonesia | -0,37 | 350 |  |
| Morocco | -0,31 | 2081 | 2081 |
| Madagascar | -0,29 | 3370 | 3273 |
| South Africa | -0,14 | 1101 | 1101 |
| Zambia | 0,14 | 4725 | 4725 |
| Vietnam | 0,23 | 134 |  |
| United States | 0,4 | 690 |  |
| Poland | 0,51 | 1670 |  |
| Cuba | 0,69 | 3694 |  |
| Botswana | 0,99 | 248 |  |
| Finland | 1 | 2308 | 12393 |
| Australia | 1,05 | 6012 | 3200 |
| Canada | 1,26 | 6969 | 6355 |
| Belgium | 0,44 |  | 6329 |
| Japan | 0,98 |  | 4305 |
| Norway | 1,2 |  | 3541 |
| France | -0,1 |  | 119 |
| India | -0,95 |  | 100 |
| Total negative WGI score |  | **-7,76** | **-5,85** |
| Total Positive WGI score |  | **6,27** | **6,07** |

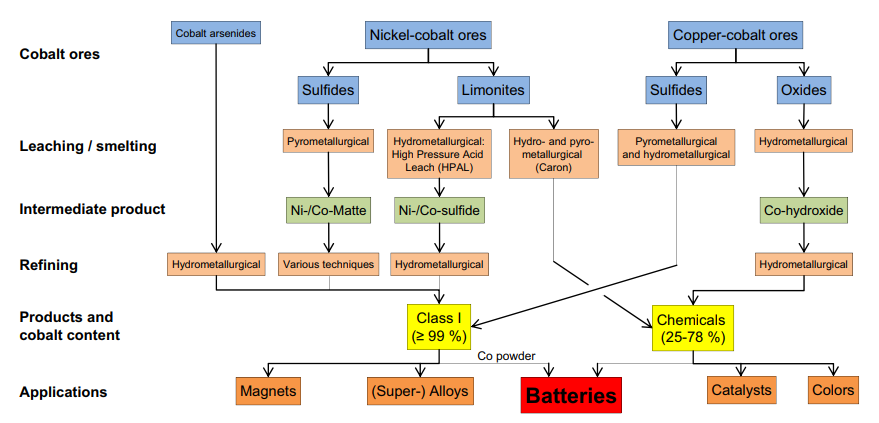
Table S5: Environmental Performance Indicator weighted to cobalt mined and refined production (Hsu, A. et al. , 2016).)

|  |  |  |  |
| --- | --- | --- | --- |
| **Country** | **Environmental Performance Indicator (2016)** | **Mined production country (t) (BGS, 2018)** | **Refined production (t) (BGS, 2018)** |
| Australia | 87 | 6012 | 3200 |
| Botswana | 71 | 248 |  |
| Brazil\* | 79 | 3600 | 400 |
| Canada | 85 | 6969 | 6355 |
| China\* | 65 | 10500 | 45046 |
| Cuba | 79 | 3694 |  |
| DRC | 42 | 68822 | 400 |
| Finland | 91 | 2308 | 12393 |
| Indonesia\* | 66 | 350 |  |
| Madagascar | 37 | 3370 | 3273 |
| Morocco | 74 | 2081 | 2081 |
| New Caledonia |  |  | 2531 |
| Papua New Guinea | 48 | 2191 |  |
| Philippines | 74 | 2554 |  |
| Poland | 81 | 1670 |  |
| Russia | 84 | 2100 | 2100 |
| South Africa | 71 | 1101 | 1101 |
| United States | 85 | 690 |  |
| Vietnam | 59 | 134 |  |
| Zambia | 66 | 4725 | 4725 |
| Zimbabwe | 59 | 409 |  |
| Belgium | 80 |  | 6329 |
| France | 88 |  | 119 |
| India | 54 |  | 100 |
| Japan | 81 |  | 4305 |
| Norway | 87 |  | 3541 |
| **Total Production** |  | **123528** | **97999** |
| **Weighted EPI** |  | **56** | **71** |

Table S6: References to all company websites and annual reports.

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Figure S1: Most important current nickel primary production routes, intermediate products, nickel content and applications.



**Source:** Schmidt, T., Buchert, M., Schebek, L. Investigation of the primary production routes of nickel and cobalt products used for Li-ion batteries. Resources, Conservation and Recycling, 112, 107–122. http://dx.doi.org/10.1016/j.resconrec.2016.04.017

Examples of leaching/smelting on site:

* At the Moa Bay mine there is the Moa Bay nickel smelter “Moa uses an open-pit mining process to mine lateritic ore, which is processed using  high-pressure acid leaching on-site into mixed sulphides containing nickel and cobalt”.(Sherritt, 2019, <https://www.sherritt.com/English/operations/metals/Moa/default.aspx> ,accessed August 2019)
* At the Rio Tuba Nickel mine in the Philipiines, Coral Bay Nickel Corporation operates a Hydrometallurgical Processing Plant (HPP) to produce nickel and cobalt sulfide from existing stockpiles of low grade nickel ores from the Rio Tuba nickel mine (Coral Bay Nickel, 2019, <http://coralbaynickel.com/>, accessed August 2019)
* At the Nchanga mine in Zambia , Konkola copper mines operates the Konkola smelter (Konkola Copper Mines, <http://kcm.co.zm/our-operations/mining-process/> , accessed August 2019)
* At the ruashi mine in the Democratic Republic of the Congo Meteorex operates a modern solvent extraction electro-winning plants ( Meteorex, 2019, <http://www.metorexgroup.com/mine/ruashi-mining/> ,accessed August 2019)

Figure S2: Map of the Central African Copper Belt giving an overview of DRC’s industrial and artisanal coppercobalt mines as well as refineries and smelters (BGR 2017b)

