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Optimizing quality of information in RAw MAterial data collection across Europe

D3.3: Producing flows & Sankey diagrams

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Author(s):	J.M. Mogollón, T. Yamamoto
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Purpose

The purpose of this brief document is to provide a basic description of the generation of the Sankey diagrams at national level of datasets within the EU-UMKDP and the development of a Web-based dedicated application prototype with an adapted graphical user interface (Deliverable 3.3). This visual tool directly compares primary production with market demand for materials related to the electrical and electronic equipment (EEE), vehicle, and battery sectors, in addition to the elemental waste flows from these sectors.

Datasets used

The Sankey diagram uses information from 2 main sources, with primary element information:

1. The European Minerals Yearbook hosted in the 'European Intelligence Network for Europe' (Minerals4EU) project. This project was a collaboration of 26 European national geological surveys and 5 other institutions, funded by the European Union Seventh Framework Programme. It contains data for primary minerals production, trade, resources and reserves for each European country. This dataset is available at: http://minerals4eu.brgm-rec.fr/m4eu-yearbook/.
2. The Urban Mine Platform database displays all readily available data on products put on the market, stocks, composition and waste flows for electrical and electronic equipment (EEE), vehicles and batteries for all EU 28 Member States plus Switzerland and Norway. This database was produced by the Prospecting Secondary raw materials in the Urban mine and Mining wastes (ProSUM) project, which created the first centralized database of all available data and information on stocks, flows and treatment of waste electrical and electronic equipment (WEEE), end-of-life vehicles, and batteries. This dataset is available at http://www.urbanmineplatform.eu/homepage

Methodology overview

The Sankey diagrams are produced for every element represented in both datasets for a particular nation and year. The combination of these datasets contains sufficient information to compare flows coming from raw materials with respect to market demand for materials related to the EEE, vehicle, and battery sectors, in addition to the elemental waste flows from these sectors as shown in Figure 1. Flows for Primary Production (green arrows), imports (yellow arrows), exports (gray arrows), and waste (pink arrows) are available from these two databases, for the circled sectors. The algorithm has been made flexible to the extent that new sectors not addressed in ORAMA (e.g. the Built Environment) can eventually be incorporated in future versions.

For the purposes of the graphical representation of the Sankey diagrams, a deterministic model was implemented, by balancing the flows with respect to one unknown, the net imports to put on market (purple arrow). This method maintains the curated databases coming from ProSUM and Minerals4EU intact, as these databases have already been balanced and assessed in previous EU projects.

The Sankey diagrams are produced on a yearly basis for all common years in the datasets. Multiple years for a country are overlain into a graphical movie representation to observe the relative flow changes within each year and between years.

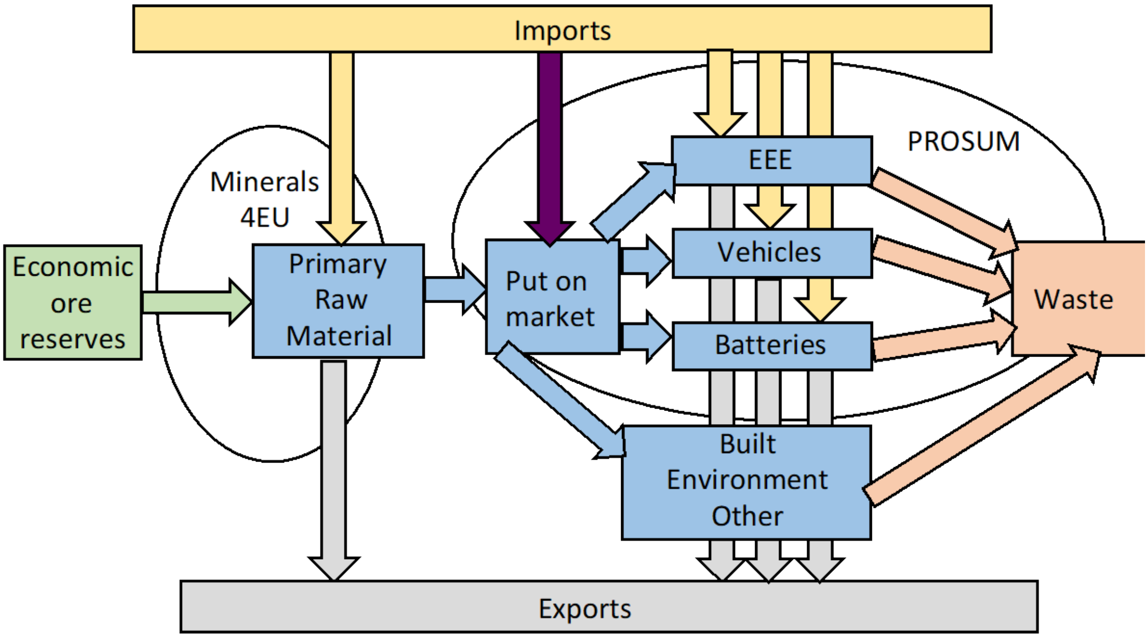

Figure 1: Flows for Primary Production (green arrows), imports (yellow arrows), exports (gray arrows), and waste (pink arrows). The circled areas represent the two compiled databases used for the Sankey generator. The purple arrow represents the net imports of materials to be put on the market as calculated from these two datasets.

Data harmonization

Data from the Urban Mine Platform is available at the element level. However, the data obtained from the Minerals4EU is available at the commodity (ores, oxides, metals, etc) level. To harmonize these values we made a literature compilation of various concentrations for element concentration present in these various commodities. While these values represent literature averages, and thus do not account for any ore grade decrease or for regional differences. In the event of improved statistics on this information they can be directly implemented into the conversion tables. Table 1 contains the information currently implemented in the commodity to element conversion for the Minerals 4EU database as the ORAMA conversions. Note that, other compilations are also available, for instance, from the Global Materials Flow Database (GMFD, https://www.resourcepanel.org/global-material-flows-database). GMFD is a joint project between the International Resource Panel and the United Nations Environment. These two conversion tables may contain some divergences (Table 2). In order to create more flexibility in the viewing of different possible compiled element concentrations within an ore, in the future we will implement user choice for the conversions via the graphical user interface.

Graphical User Interface

The graphical user interface (GUI) presents a simple selection of element and country that directly calls a python-based algorithm to retrieve, harmonize, and balance the data for all available years of the particular selection. The GUI is available at the Urban Mine Platform via http://prosum.brgm-rec.fr/sankey (until 12/2019) http://www.prosumproject.eu/**sankey** (afterward). In the GUI, the user can select an element and a EU member state to display the flows for a given set of years that contain both primary raw material extraction (Minerals4EU) and put on the market (ProSUM) information.

Table 1: ORAMA conversions: Element concentrations in various Minerals4EU commodities

Element	Commodity (production category)	Proportion	Commodity (trade category)	Proportion
[1]Aluminium	Alumina	5.29E-01	Alumina	5.29E-01
	Bauxite	2.78E-01	Bauxite	2.78E-01
	Primary aluminium	1	Aluminium	1
Antimony	Antimony, mine	1	Antimony	1
Arsenic	White arsenic	7.58E-01	Arsenic	1
Bismuth	Bismuth, mine	1	Bismuth	1
[2]Cadmium	Cadmium	1	Cadmium	1
[3]Chromium	Chromium ores and concentrates	3.22E-01	Chromium	1
Cobalt	Cobalt metal	1	[10]Cobalt oxides	7.43E-01
	Cobalt, mine	1	[10]Cobalt ore	0.1
Copper	Copper, mine	1	[11]Copper matte and cement	5.28E-01
	[4]Copper, refined	1	[12]Copper ores and concentrates	2.73E-01
	Copper, smelter	1		
Germanium	Germanium metal	1	Copper, unwrought	1
Gold	Gold, mine	1	Gold	1
Graphite	Graphite	1	Graphite	1
Indium	Indium, refined	1	Crude steel	9.80E-01
Iron and steel	[5]Crude steel	9.80E-01	Iron ore	6.40E-01
	[6]Iron ore	6.55E-01	Pig iron	9.20E-01
	[7]Pig iron	9.20E-01	[13]Lead ores and concentrates	1.46E-01
Lead	Lead, mine	1	Lead unwrought	1
	Lead, refined	1	Lithium carbonate	1.88E-01
Lithium	Lithium	1	Lithium oxides	1.92E-01
Magnesite	Magnesite	2.88E-01	Magnesite and magnesia	1
Magnesium	Magnesium, primary metal	1	Manganese metal	1
Manganese	[8]Manganese ore	4.40E-01	Manganese ores and concentrates	4.40E-01
Mercury	Mercury	1	Mercury	1
Molybdenum	Molybdenum, mine	1	Molybdenum metal and oxides	8.05E-01
			[14]Molybdenum ores and concentrates	8.66E-04
[9]Nickel	Nickel, mine	1	Nickel mattes, sinters, etc	1
	Nickel, smelter/refinery	1	Nickel metal	1
			[15]Nickel ores and concentrates	8.00E-03
			Nickel oxides	5.70E-01
Platinum group	Platinum group metals, mine	1	Platinum group metals	1.00E+00
Silver	Silver, mine	1	Silver metal	1
			[16]Silver ores and concentrates	1.28E-04
Tin	Tin, mine	1	[17]Tin concentrates	5.50E-01
	Tin, smelter	1	Tin metal	1
Tungsten	Tungesten, mine	1	Tungsten carbide	9.39E-01
			Tungsten metal	1
			[18]Tungsten ores and concentrates	4.20E-01
Zinc	Zinc, mine	1	[19]Zinc ores and concentrates	4.90E-02
	Zinc, slab	1	Zinc unwrought	1
Zirconium	Zirconium minerals	6.19E-01	[20]Zirconium concentrates	6.19E-01
			Zirconium metal	1

[1]The typical Bayer process bauxite grade is 50 - 55 % Al2O3 https://www.azom.com/article.aspx?ArticleID=12163, 30% to 60% Al2O3. https://link.springer.com/content/pdf/10.1007/s11837-001-0011-1.pdf

[2]The only cadmium mineral of importance, greenockite (CdS), is nearly always associated with sphalerite (ZnS).

[3]https://waset.org/publications/10005215/beneficiation-of-low-grade-chromite-ore-and-its-characterization-for-the-formation-of-magnesia-chromite-refractory-by-economically-viable-process. Chromite is economic ore of chromium, Cr/FE ratio > 2 andcointaining a minimum of 46 to 48% Cr2O3.

[4]Depends on the refining process

[5]https://educalingo.com/en/dic-en/crude-steel

[6]Magnetite (Fe3O4, 72.4% Fe), hematite (Fe2O3, 69.9% Fe), goethite (FeO(OH), 62.9% Fe), limonite (FeO(OH)·n(H2O), 55% Fe) or siderite (FeCO3, 48.2% Fe) https://en.wikipedia.org/wiki/Iron_ore.https://www.sciencedirect.com/topics/materials-science/iron-ore

[7]https://www.metallics.org/pig-iron.html

[8]Assuming pyrolusite (MnO2). https://www.researchgate.net/figure/Chemical-composition-of-the-pyrolusite-ore_tbl1_224771054

[9]Purification of *nickel* oxides to obtain the purest metal via the Mond process, which increases the *nickel* concentrate to greater than 99.99% *purity*.

[10]https://www.bgs.ac.uk/downloads/start.cfm?id=1400, the oxides represent an average of various oxide concentrations

[11]Copper cement (copper, copper oxide and copper sulphate) assuming copper oxide 0.75, copper sulfate 0.4 https://brainly.in/question/2218672

[12]Concentrate usually 27-29% https://en.wikipedia.org/wiki/Copper_extraction, https://en.wikipedia.org/wiki/List_of_copper_ores

[13]http://azr.com/documents/Lead_concentrate_EU_%28GHS_SDS_Mar_2017%29.pdf. PbCl2 (207/278), PbSO4 (207/303) and lead fluorides (207/245)

[14]Molybdenite concentrate (MoO3)is generally at 0.01-0.25% https://www.imoa.info/molybdenum/molybdenum-ore-reserves.php

[15]http://www.amegroup.com/Website/FeatureArticleDetail.aspx?faId=159

[16]Important ores of silver are: Argentite (Ag2S), Copper silver glance, Horn silver (AgCl), Ruby silver (Ag3SbS3). Average yield of 4-5 ounces per ton. https://chem.libretexts.org/Bookshelves/Inorganic_Chemistry/Supplemental_Modules_(Inorganic_Chemistry)/Descriptive_Chemistry/Elements_Organized_by_Block/3_d-Block_Elements/1b_Properties_of_Transition_Metals/Metallurgy/The_Extraction_of_Silver Today, the Primary Silver Mining

[17]45-65% http://laomining.com/tin tin sand from Lao, https://original.metal.com/metals/productinfo/201605260001 70%

[18]Marketable ores of scheelite and wolframite (hübnerite, ferberite) contain typically 65 – 70 % WO3. https://en.wikipedia.org/wiki/Tungsten_ore

[19]Weighted zinc grade may increase from 4.9% in 2017 to 5.2% in 2030. http://www.amegroup.com/Website/FeatureArticleDetail.aspx?faId=373

[20]Zirconium is found in two minerals, zircon (zirconium silicate, ZrSiO4) and baddeleyite (zirconium oxide, ZrO2), the former is more important

Table 2 Comparison of values in ORAMA and Global Materials Flow Database

	ORAMA	Global Materials Flow Database			
	(Table 1)	min	max	median	mean
Bauxite	2.78E-01	0.00E+00	6.00E-01	3.92E-01	4.04E-01
Cobalt ore	1.00E-01	3.00E-03	1.00E+00	1.00E+00	9.41E-01
Copper ores and concentrates	2.73E-01	2.30E-03	1.00E+00	9.05E-03	1.01E-01
Iron ore	6.40E-01	0.00E+00	6.33E-01	4.44E-01	4.39E-01
Lead ores and concentrates	1.46E-01	4.64E-04	1.00E+00	3.62E-03	1.35E-01
Manganese ores/ concentrates	4.40E-01	2.00E-01	4.74E-01	3.29E-01	3.17E-01
Molybdenum ores/concentrates	8.66E-04	1.90E-04	1.00E+00	1.90E-03	3.34E-01
Nickel ores and concentrates	8.00E-03	2.00E-03	1.00E+00	1.71E-02	2.05E-01
Silver ores and concentrates	1.28E-04	6.70E-06	1.00E+00	3.00E-04	1.51E-01
Tungsten ores and concentrates	4.20E-01	1.65E-03	9.80E-03	5.15E-03	5.03E-03
Vanadium ores and concentrates	3.36E-03	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Zinc ores and concentrates	4.90E-02	1.19E-04	2.25E-02	2.33E-03	5.13E-03