13 INDIUM

13.1 Overview

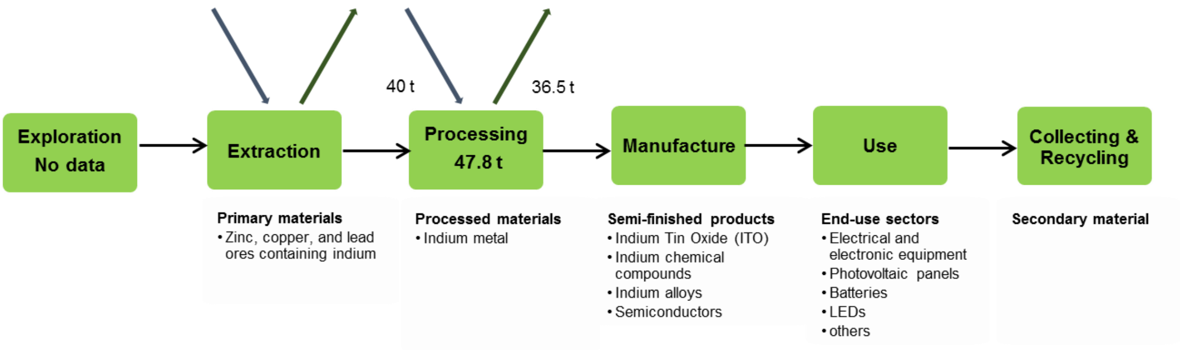

Figure 156: Simplified value chain for indium, 2012-2016 for the EU, averaged over 2012 to 2016[119]

Indium (chemical symbol In, atomic number 49) is a very soft, ductile and malleable silvery metal with a hardness of 1.2 on Mohs scale. It has a density of 7.31 g/cm^3 (similar to tin's), a low melting point of 156.6°C, a high boiling point of 2072°C and becomes superconducting at 3.37 K (-269,78°C). The most important commercial source of indium is the zinc mineral sphalerite. Approximately 95% of the refined primary indium produced in the world comes from zinc ores processing (Lokanc, M. et. al., 2015).

Indium is assessed at processing stage (indium metal), by considering trade of unwrought indium; Indium powders (trade code CN81129281)

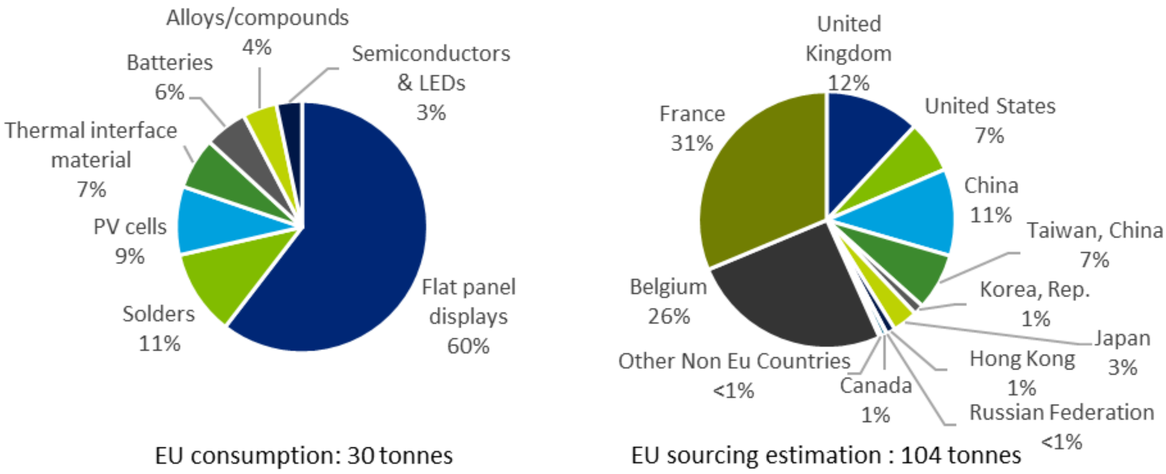

Figure 157: End uses of indium (SCRREEN, 2019)[120] and annual average EU sourcing of indium, 2012-2016[121]

The worldwide market value of indium in 2019 was USD 420 million and it is expected to grow at a CAGR of roughly 4.2% over the next five years, reaching USD 540 million in 2024 (Marketwatch, 2019). Indium is traded in metal exchange. The price of indium has

[119] JRC elaboration on multiple sources

[120] Apparent consumption figure for indium is derived from adding EU production (based on the figures reported by World Mining Data, 2019) and imports and subtracting exports (imports and exports figures are based on the information reported by Eurostat-Comext, 2019)

[121] EU sourcing figure of indium, 104 tonnes, is the sum of EU production (based on World Mining Data, 2019) and EU imports (based on Eurostat, Comext, 2019)

decreased from USD 718 per kilogram in 2014 to USD 263 per kilogram in 2018. The collapse of Fanya Metals Exchange in China, which has accumulated large amounts of indium metal in 2015 was associated to this trend (USGS, 2016b).

Over the period 2012-2016 the EU imported 34 tonnes of indium annually, mainly from the United Kingdom (13% of EU sourcing), followed by the United States (5% of EU sourcing) and China (4% of EU sourcing). Indium was domestically produced in the EU in France (29.25 tonnes per year, representing 31% of EU sourcing) and Belgium (23.75 tonnes per year, 26% of EU sourcing).

The major use of indium in the EU is as indium-tin oxide (ITO) in flat panel devices (FPDs). Other applications include alloys and solders, thin film solar panels, thermal interface materials, light emitting diodes (LEDs) and laser diodes. In transparent conducting oxides (TCOs) used in flat panels displays and in amorphous silicon and CdTe PV cells, indium can be replaced by other TCOs. There is no commercially available substitute for indium in semiconductors (CIGS and CIS) used in thin-film solar cells.

Given its use in PV cells and in batteries, indium can play a role in enabling low-carbon energy solutions in the EU economy, contributing to achieve the objectives of the "European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy"[122].

Indium resources and reserves are generally derived from zinc resources and reserves data using an average indium content of zinc ores. A study undertaken by the Indium Corporation estimated that primary indium resources and reserves in identified base metal mines amounted to approximatively 50,000 tonnes of indium, with some 47% in China and the Commonwealth of Independent States (CIS), and 53% in other countries (Mikolajczak, 2009). In Europe, most of the indium mineralisation is located in Variscan units and, to a small extend, in Proterozoic (Sweden), Caledonian and Alpine formations. Indium resources were also reported to exist in Austria, Bulgaria, Czechia, Germany, Greece, Hungary, Ireland, and Portugal (Lauri, L. et. al., 2018).

World production of indium over 2013-2016 was 827 tonnes, with majority of production in China (48%), followed by South Korea (21%) (WMD, 2019). The EU production of indium accounted for 9% of the global supply over the same period (WMD, 2019).

World secondary refined indium production resulted almost exclusively from the recycling of manufacturing waste (new scrap) rather than recovery from end-of-life (EoL). Indium is most commonly recovered from ITO scrap, for example in Japan and the Republic of Korea (USGS, 2019). Precise data on the amount of secondary indium recovered from scrap are not available, though are estimated to exceed primary indium production (European Commission, 2017). However, when it comes to old scrap, only a very little share of old scrap (1%) is recycled worldwide (UNEP, 2013).

Prior to 2017, China imposed 2% export tax on indium and an export quota at 237 tonnes on average. Both measures have been removed in 2017. China has applied export licences since January 2017 (European Commission, 2017).

Indium tin oxide and indium phosphide are both subject to registration under the EU REACH regulation (ECHA, 2019a) (ECHA, 2019b).

[122] COM(2018) 773 final A Clean Planet for all. A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy

13.2 Market analysis, trade and prices

13.2.1 Global market analysis and outlook

Indium-tin oxide (ITO) was the leading global use of indium (USGS, 2016a). China and Korea were the major producers of ITO over the period 2013-2016, and at the same time, together with Japan and Taiwan a major consumer of indium tin oxide. The main ITO producers, are, among others, Samsung Corning Precision materials Korea Co. Ltd. and Heesung metal Ltd. in the Republic of Korea and JX nippon mining & metals Corp. and mitsui metal mining Co. Ltd. in Japan (USGS, 2016b). All flat panel displays (FPDs) manufacturing takes place in Japan, South Korea and China. Ex-Asia, indium was mostly used in the manufacturing of non-ITO applications such as solders, alloys, and compound semiconductors.

There is no solid forecast for demand and supply of indium reported from experts. The trend in the use of indium in flat display and PV panel applications would require a slightly decreasing amount of indium towards 2035. The future indium demand would most likely follow the trends shaped by flat displays application. Several factors may contribute to accelerating the decrease in indium requirements, such as the ban of the import of e-waste from EU by other countries, increase in ITO sputtering process efficiency, recycling cost of end-of-life products and legal barriers to disposal and incentive measures in favour of reuse, repair and refurbished items. On the contrary, shift in user experience design towards display interaction may reduce the decrease in indium requirements (Monnet, A. et. al., 2018).

According to USGS (2016b), on the supply side, China is expected to continue to be the main global supplier of primary indium metal.

Table 69: Qualitative forecast of supply and demand of indium

Materials	Criticality of the material in 2020		Demand forecast			Supply forecast		
	Yes	No	5 years	10 years	20 years	5 years	10 years	20 years
Indium	x		?	?	?	?	?	?

13.2.2 EU trade

The trade flow data of indium from Eurostat indicated that over the period 2012-2016 EU was a net exporter of Indium (see Figure 158). Over the period 2012-2016 the EU imported 34 tonnes per year of indium metal, mainly from the United Kingdom (13% of EU sourcing), followed by the United States (5% of EU sourcing) and China (4% of EU sourcing) (Figure 159).

There was a high variation in export quantity of Indium in 2013 and 2014 which makes the reliability of the trade data questionable (CRM Alliance, 2019). Therefore, for the purpose of this criticality assessment, the EU trade figure for indium was calculated on the average of the year 2012, 2015 and 2016.

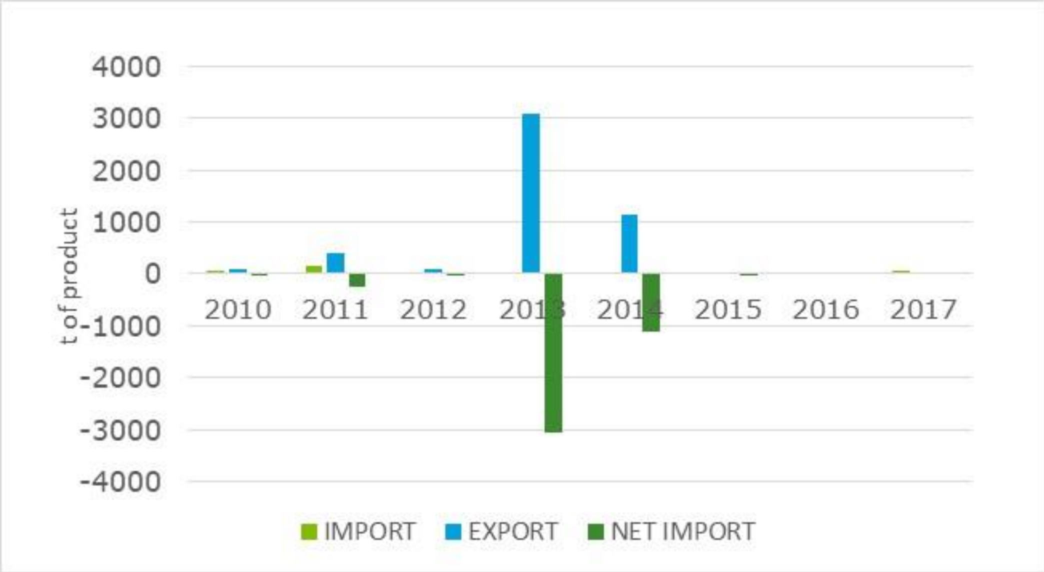

Figure 158: EU trade flows for indium metal (Eurostat, 2019a)

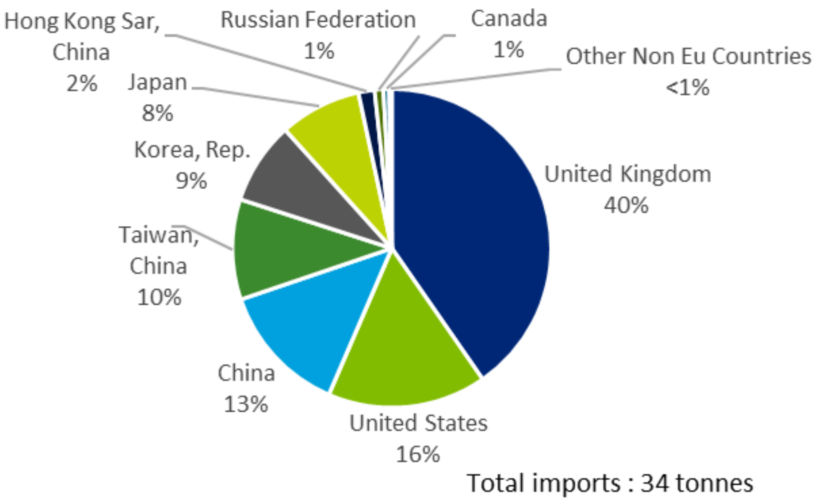

Figure 159: EU imports of indium by country (yearly average 2012-2016) (Eurostat, 2019a)

13.2.3Prices and price volatility

The price trend of indium ingots from 2014-2018 is shown in Figure 160. Prices of indium were supported by stockpiling at the Fanya Metals Exchange (FME) which was established in 2011 in Kunming, China, until its collapse in August 2015.

In 2015, Kunming municipal government announced a criminal investigation against FME for illegal fund raising. Since the collapse of FME, indium prices have dropped from USD 700 to USD 200 per kilogram in 2018 (USGS, 2016a).

Earlier in 2019, prior to the retrial against the FME’s owner at the Yunnan superior court, the Kunming court held two auctions of stocks from FME. The Yunnan court's decision indicates that the authorities are likely to hold more auctions of Fanya stocks in the future.

Approximately 3,600 tonnes of indium metal (equivalent to more than 4 years of primary production) were accumulated in FME warehouses (Argus media, 2019). Market participants have warned that a possible sudden release of these stocks could cause a price collapse in the spot market of indium (Argusmedia, 2019).

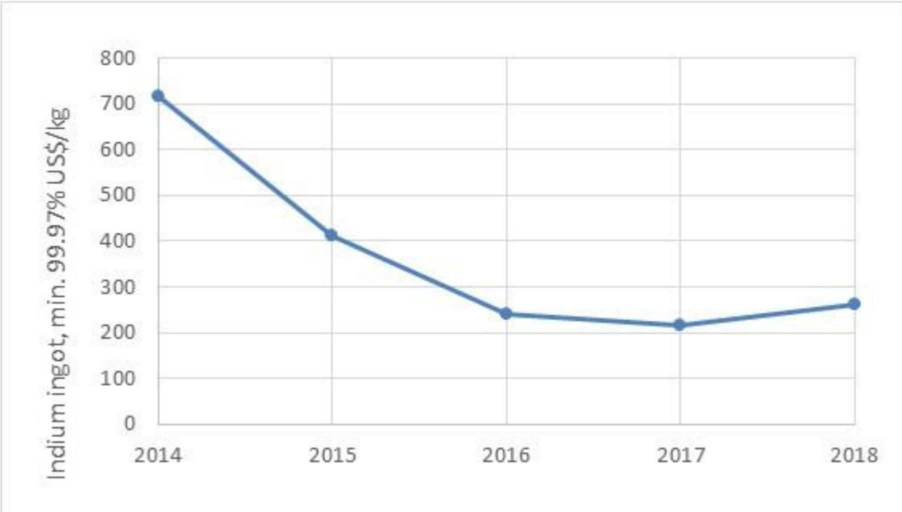

Figure 160: Indium prices from 2014 to 2018 in USD per kg of ingots, min. 99,97 % (free market, in warehouse) (DERA pricemonitor)

13.3 EU demand

13.3.1 EU demand and consumption

The EU domestic production of indium was 70.5 tonnes per year for the average of the years 2013-2017. The EU import of indium was 34,5 tonnes per year and the exports was 40 tonnes per year. As reported in "EU Trade" section, due to the data anomaly, the reported trade figures refer to the average of 2012, 2015 and 2016. Based on these figures, the estimated EU apparent consumption of indium (production+imports–exports) was 64 tonnes per year, representing 9% of the indium produced globally on average 2013-2016. The figures also suggested that the EU was a net exporter of primary indium. However, this figure may not reflect the full picture of the EU situation, since there was no official information on the quantity of indium produced from secondary supply.

13.3.2 Uses and end-uses of indium in the EU

Indium manufactured in the EU is mainly used in form of ITO in various display technologies for electronic equipment and to a lesser extend in smart windows for architectural and automotive glasses. Other uses comprise alloy additions for batteries, solders and to a smaller fraction in semiconductor compounds for solar cells and LEDs.

Indium is used for the following application:

- The primary application of indium is as ITO thin films. ITO is a mixture of indium (III) oxide (In_2O_3) and tin (IV) oxide (SnO_2), typically 90% In_2O_3, 10% SnO_2 by weight. When deposited as thin film on glass or clear plastic it functions as a transparent electrode. ITO is used in flat-panel displays (FPDs) - whether liquid crystal displays (LCDs), plasma display panels (PDPs) or OLED displays (organic light emitting diodes) - for televisions, laptops, notebooks and mobile phones. ITO thin films are also applied to car and aircraft windshields for defogging and deicing. They were still used to make touch screen cathode ray tubes (CRTs) found, e.g., in some banks ATMs, although these are slowly being phased out (Vulcan, 2013). All flat panel displays are made in Japan, South Korea and China. This application accounted for 56% of the global indium use in 2013 (Indium Corporation, 2013).

- Indium is used as a low-temperature solder and a lead-free solder, either as alloys or as pure metal. Indium reduces the melting point in solder alloys and can improve the thermal fatigue performance of solders used in the electronics industry, even in a small amount. Its ductility and malleability are retained at cryogenic temperatures so that an assembly can maintain an effective seal, even in harsh environments. Indium solders are also used for glass-to-glass or glass-to-metal joints.
- Indium semiconductor compounds ($CuIn1\text{-}xGaSe_2$) are used as a light absorber material in CIGS (Copper indium gallium diselenide) and CIS (without gallium) thin film solar cells. ITO (indium tin oxide) is used as a top transparent electrode of CIGS, amorphous silicon and CdTe cadmium telluride PV cells. The transparent conductive oxide (ITO) maximizes light transmission of the incoming light into the solar cell absorber materials (CIGS, amorphous silicon or cadmium telluride layers).
- Because of its excellent thermal conductivity and ductility, indium metal, alloys and composites are used as thermal interface materials (TIMs) in electronics devices. TIMs transfer heat generated by semiconductors to a heat sink to prevent the device from overheating. The extreme malleability of indium allows it to fill in any microscopic gaps between the two surfaces, thereby increasing heat flow.
- Indium is one of many substitutes for mercury in alkaline batteries to prevent the zinc anode from corroding and releasing hydrogen gas. Indium functions like mercury by forming zinc alloy to inhibit zinc corrosion.
- Indium is a component of low melting-point alloys which can be used for glass-to-glass or glass-to-metal joints and in a variety of other applications: in semiconductor compounds in LEDs (e.g. indium gallium nitride-InGaN), laser diodes (indium phosphide InP), etc. Relevant industry sectors are described using the NACE sector codes (Eurostat, 2019b).
- Furthermore, Indium in indium antimonide (InSb) and indium gallium arsenide (InGaAs) are used for infrared technologies. Indium phosphide (InP) is used for laser diodes.

Figure 161 presents the share of main uses of indium in the EU. The Relevant industry sectors for the application in of indium in the EU are described using the NACE sector codes (Eurostat, 2019b), presented in Table 70.

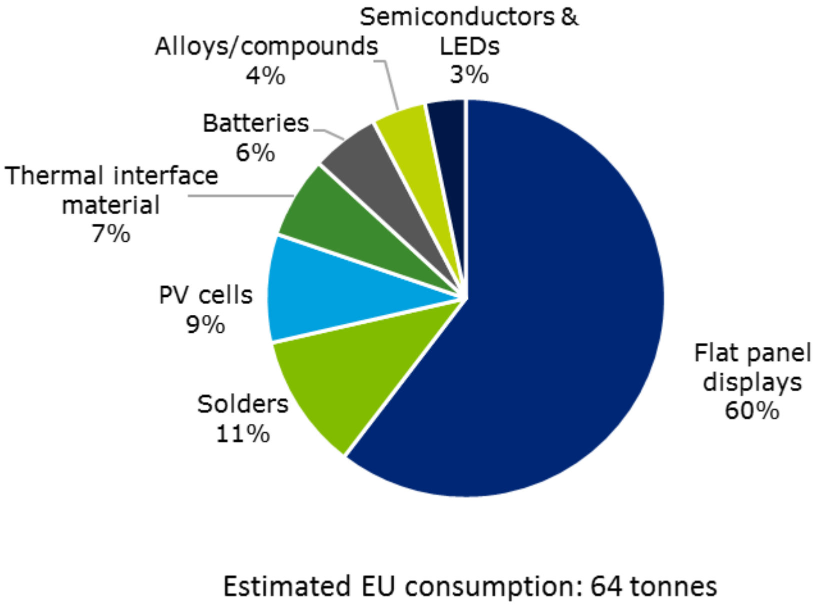

Figure 161: EU end uses of indium (SCRREEN, 2019). Average figures for 2012-2016 (see EU demand section).

Table 70: Indium applications, 2-digit and associated 4-digit NACE sectors, and value added per sector (Eurostat, 2019b)

Applications	2-digit NACE sector	4-digit NACE sectors	Value added of sector (millions €)
Flat panel displays	C26 - Manufacture of computer, electronic and optical products	C26.2.0 - Manufacture of computers and peripheral equipment	75,260
Solders	C26 - Manufacture of computer, electronic and optical products	C26.1.1 - Manufacture of electronic components	75,260
PV cells (CIGS, CIS and CdTe)	C26 - Manufacture of computer, electronic and optical products	C26.1.1 - Manufacture of electronic components	75,260
Thermal interface material	C26 - Manufacture of computer, electronic and optical products	C26.1.1 - Manufacture of electronic components	75,260
Batteries	C27 - Manufacture of electrical equipment	C27.2.0 - Manufacture of batteries and accumulators	84,609
Alloys/compounds	C24 - Manufacture of basic metals	C24.4.5 - Other non-ferrous metal production	57,000
Semiconductors & LEDs	C26 - Manufacture of computer, electronic and optical products	C26.1.1 - Manufacture of electronic components	75,260

13.3.3Substitution

Substitute options are presently available for some major indium containing applications in the EU (Tercero, et. al., 2018):

- *Flat display application:* indium-thin-oxide (ITO) is substitutable in LCDs by antimony-tin-oxide (ATO). However, antimony is no real substitute option as it is also classified as critical raw material (European Commission 2017a). For architectural glasses with low emissivity coating, ITO can be replaced by Fluorine-doped-thin-oxide (FTO). For smart window applications with double glazing (moisture protected) Aluminium-doped-Zinc-Oxide (AZO) or Zinc Oxide (ZnO) can be used for ITO. In thin film solar cells and flat panel displays, it is possible to use FTO or AZO as Transparent Conductive Oxide (TCO) instead of ITO, however not without a loss in performance with respect to conductivity and/or transparency.

- *PV cells application:* CdTe or a-Si based thin film solar cells can be used instead of CIGS/CISbased semiconductors in thin film solar cells. InP can be replaced in laser diodes by GaAs. However, Ga is also classified as critical raw material, which makes this substitute option obsolete.
- *Solder application:* Tin-bismuth alloys can replace tin-indium alloys for low temperature bonding and soldering applications. Similarly, for cryogenic sealing applications, lead-based alloys can be used instead of indium and indium-tin alloys. Hafnium replaces indium in nuclear reactor control rods. Alloy additions for batteries, solders and to a smaller fraction in semiconductor compounds for solar cells and LEDs.

13.4 Supply

13.4.1 EU supply chain

- At extraction stage, some of the zinc concentrates produced in the EU present significant indium contents. At Neves Corvo in Portugal, indium grades vary within the range 20 to 1,100 ppm per tonne in the massive zinc and lead-zinc ores of the deposit (Pinto et al., 2014). However it is not known if indium was recovered from concentrates produced within the EU during the period 2012-2016. In general, the quantity of indium recoverd from zinc concentrates produced globally are not publicly reported.
- At refining stage, the EU has refining capacity, producing up to 70.5 tonnes of refined primary indium per year on average over the year 2013-2016.
- At recycling stage, the EU also has a refining capacity for secondary indium. However, these figures are not reported publicly. The total estimated EU production capacity reported for the year 2013 was 51.5 tonnes per year (Lokanc, M. et al, 2015).

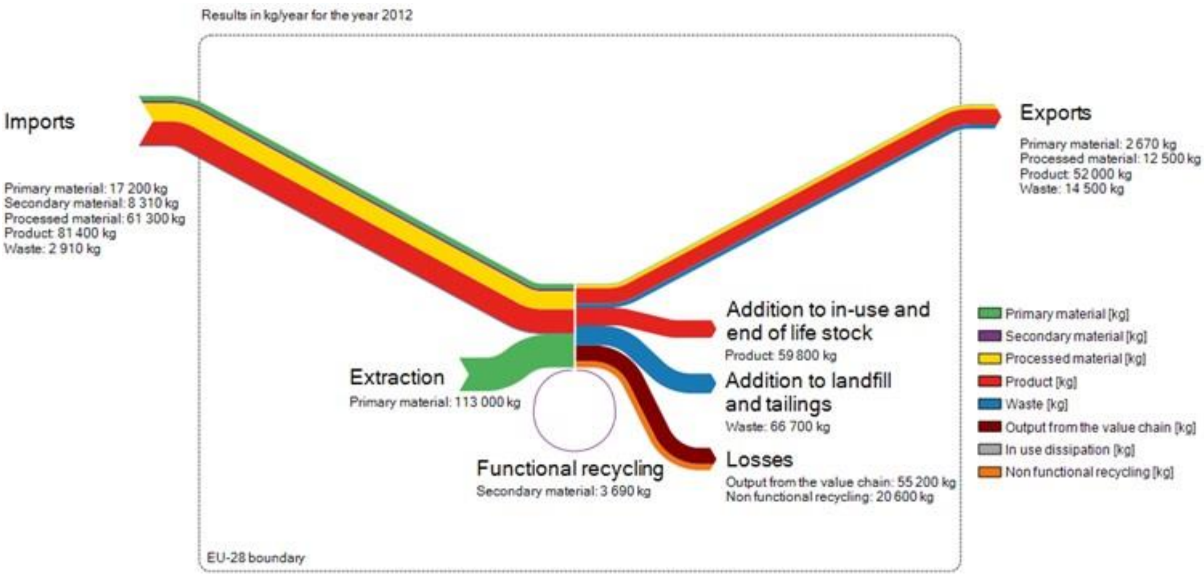

Figure 162: Simplified material system analysis diagram of indium in the EU, reference year 2012 (BioIntelligence, 2015)

13.4.2Supply from primary materials

13.4.2.1 Geology, resources and reserves of indium

Geological occurrence:

Indium is found as a trace element in some zinc, copper, lead and tin minerals but is mostly recovered from the zinc-sulphide mineral sphalerite. Indium abundance in the Earth continental upper crust is estimated at 0.056 ppm (Rudnick & Gao, 2014).

The most important deposits are volcanic and sediment-hosted base-metal sulphide deposits, which are generally characterised by high metal abundance and large tonnages. The concentration of indium in these ores is in the range 20–200 ppm. Other types of deposits containing significant and recoverable amounts of indium include polymetallic vein-type deposits, vein-stockwork deposits of tin and tungsten and epithermal deposits (Schwarz-Schampera, 2014).

Global resources and reserves[123]*:*

Being mainly recovered as a by-product of zinc production, indium resources and reserves are generally derived from zinc resources and reserves data using an average indium content of zinc ores.

A study undertaken by the Indium Corporation (Mikolajczak, 2009) estimated that primary indium resources and reserves in identified base metal mines amounted to approximatively 50,000 tonnes of indium, with some 47% in China and the Commonwealth of Independent States (CIS), and 53% in other countries.

Global resources and reserves of indium calculated from global zinc resources and reserves reported by USGS (2012), using an average zinc ore indium content of 50 gram per tonne, have been estimated at 95,000 tonnes and 12,500 tonnes, respectively (Schwarz-Schampera, 2014). When also considering recoverable indium in copper deposits and using an average indium content of 10 gram per tonne, total resources and reserves amounted to 125,000 tonnes and 18,800 tonnes in 2012.The indium content of zinc deposits from which it is recovered ranges from less than 1 part per million to 100 parts per million (USGS, 2019).

NREL estimated as much as 15,000 tonnes of indium reserves are available from zinc ores, with the largest reserves located in China (Table 72).

[123] There is no single source of comprehensive evaluations for resources and reserves that apply the same criteria to deposits of indium in different geographic areas of the EU or globally. The USGS collects information about the quantity and quality of mineral resources but does not directly measure reserves, and companies or governments do not directly report reserves to the USGS. Individual companies may publish regular mineral resource and reserve reports, but reporting is done using a variety of systems of reporting depending on the location of their operation, their corporate identity and stock market requirements. Translations between national reporting codes are possible by application of the CRIRSCO template.[123], which is also consistent with the United Nations Framework Classification (UNFC) system. However, reserve and resource data are changing continuously as exploration and mining proceed and are thus influenced by market conditions and should be followed continuously.

Table 71: World indium resources and reserves calculated from global zinc and copper resources and reserves reported by USGS in 2012 (Data from Schwarz-Schampera, 2014)

Estimated world indium resources and reserves (tonnes of indium)	
Resources in zinc ores	95,000
Reserves in zinc ores	12,500
Resources in copper ores	30,000
Reserves in copper ores	6,300
World total indium resources	125,000
World total indium reserves	18,800

Table 72: World Indium Reserves[124] (Lokanc, M. et. al., 2015)

Country	Indium reserves (tonnes of indium)
Canada	180
China	10,400
Peru	480
Russia	80
United States	200
Other[125]	3,700
Total	15,000

EU resources and reserves*[126]***:**

There is no mineral resource and reserve data for indium reported in the Minerals4EU (2019) project. In Europe, most of the indium mineralisation is located in Variscan units and, to a small extend, in Proterozoic (Sweden), Caledonian and Alpine formations. The largest indium anomalies on the Iberian Peninsula overlap with known metallogenic districts which include deposits such as Neves-Corvo copper-zinc mine in Portugal (Ladenberger, 2015). Since indium is not recovered in all zinc and tin refineries, it is not clear how much indium is produced from the Portuguese ores (Lauri, L. et. al., 2018). Resources of indium were also reported to exist in Austrian lead-zinc deposits, copper deposit in Bulgaria, Czechia, Germany, Greece, Hungary, and Ireland (Lauri, L. et. al., 2018).

13.4.2.2 World and EU indium bearing ore production

Indium is not concentrated enough to be a major commodity in deposits, but it is recovered as a by-product mainly from residues generated during zinc ore processing. A small amount (5%) is produced as a by-product of lead, tin, and copper production (European

[124] Not included: indium in copper, lead, tin and silver deposits, or in discarded residues, slag, or tailings.

[125] Include Australia, Bolivia, India, Ireland, Kazakhstan, and Mexico

[126] For Europe, there is no complete and harmonised dataset that presents total EU resource and reserve estimates for indium. The Minerals4EU project is the only EU-level repository of some mineral resource and reserve data for indium, but this information does not provide a complete picture for Europe. It includes estimates based on a variety of reporting codes used by different countries, and different types of non-comparable datasets (e.g. historic estimates, inferred reserves figures only, etc.). In addition, translations of Minerals4EU data by application of the CRIRSCO template is not always possible, meaning that not all resource and reserve data for indium the national/regional level is consistent with the United Nations Framework Classification (UNFC) system (Minerals4EU 2019).Many documented resources in Europe are based on historic estimates and are of little current economic interest. Data for these may not always be presentable in accordance with the UNFC system. However a very solid estimation can be done by experts.

Commission, 2017). Approximatively 95% of the refined indium produced in the world comes from the processing of zinc ores (Lokanc, M. et. al., 2015).

The figures on mine production for indium as byproduct of zinc mining are not publicly available. By assuming that sphalerite ores contain 67% zinc and 15-50 ppm of indium, Roskill estimated that 629 tonnes of indium were mined from zinc ores in 2013. China, Peru, Canada, Australia, and the United States accounted for 79% of potentially recoverable indium from zinc ores in 2013 (Lokanc, M. et. al., 2015). In the EU, Ireland was estimated to have 10 tonnes of potential indium content from mined zinc ores in 2013.

The Neves-Corvo VMS-type Cu-Zn-Sn deposit contains the largest known indium resource in Europe, estimated at 3480 tonnes (Lauri, L. et. al., 2018). The Neves-Corvo mine produces zinc and tin concentrates that, probably, also contain significant amounts of indium. Since indium is not recovered in all zinc and tin refineries, it is not clear how much indium is produced from the Portuguese ores (Lauri, L. et. al., 2018).

13.4.2.3 World and EU primary indium refinery production

Indium recovered from mine concentrates requires further refining to reach the desired purity. Most indium producers are not fully integrated; mine producers usually sell indium-bearing concentrates on the open market. Indium from zinc smelting is usually sold as a sponge.

The world refinery production of primary indium was approximatively 827 tonnes per year on average over the period 2012-2016. China continued to be the major producer with almost half of the global production (48%). The remaining production was predominantly in South Korea (21% share), Japan (8%), Canada (8%), and Russia (4%) (WMD, 2019).

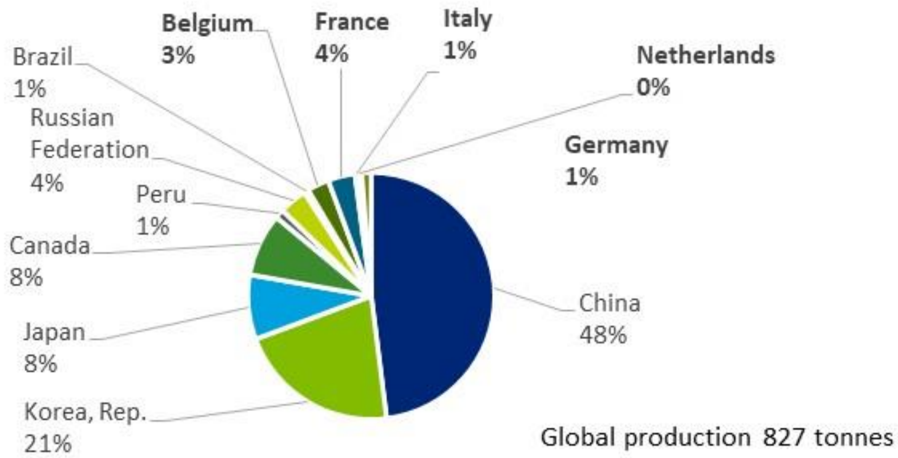

Figure 163: Global production of primary indium in tonnes and percentage. Average for the year 2012-2016. (WMD, 2019)

The EU production of refined indium amounted to 70.5 tonnes per year on average on the period 2012-2016 and represented around 8.5% of the world production. The EU production of indium in this period by country is presented in Figure 164. Most primary indium is produced as a by-product of zinc mining and refining. However, the indium content of zinc ores mined in the EU or the zinc ores imported into the EU are not published (Bio by Deloitte, 2015).

Belgium and France refined indium from imported concentrates, residues and slags. In France, Nyrstar commissioned a new virgin indium plant at Auby in 2012 which produced 43 tonnes of metal in 2014 (European Commission, 2017). Auby's zinc concentrates were sourced from suppliers world-wide (Nyrstar, 2016). No indium was produced in 2016 due to a fire incident at the indium cement plant that occurred in late 2015 (USGS, 2016b). The indium plant has since been re-built with additional capacity, bringing total production capacity to 70 tonnes per year. The production has resumed in 2017.

The other major producer was Umicore in Belgium. Umicore produced refined indium at its Hoboken plant from dusts and residues generated by its lead-copper processing plant. Umicore Precious Metals Refining produces a crude $In(OH)_3$ (Indiumhydroxide) for further refining. In 2019, they reported a capacity of 50 tonnes of indium contained products per year (Umicore, 2019). However, the exact quantitative data on the production of Belgium (Umicore) is not published.

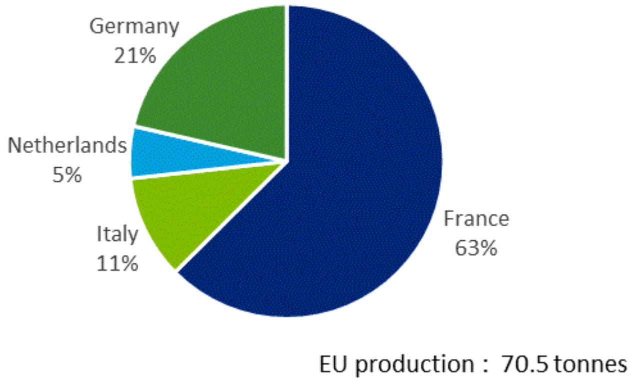

Figure 164: EU production of indium percentage. Average for the years 2013-2016. (WMD, 2019)

Germany's small production which consisted into upgrading 4N indium (99.99 In) to very high purity indium (up to 7N) (PPM Pure Metals) was not included in the EU primary production. In Germany, Saxony Minerals and Exploration AG is working at the Pöhla deposit in Saxony, Germany with the aim of starting tungsten, tin, indium and fluorite production. According to the company, pilotscale production has started in late 2017 (Lauri, L. et. al., 2018).

13.4.3Supply from secondary materials/recycling

Since the indium price increases in 1995 and in 1996, secondary production has been a significant contributor to overall supply (Lokanc, M. et. al., 2015). World secondary refined indium production resulted almost exclusively from the recycling of manufacturing waste (new scrap) rather than recovery from end-of-life (EOL).

13.4.3.1 Pre-consumer recycling (old scrap)

Most of the indium produced in the world is used in ITO (tin-doped indium oxide) thin-film coating on flat-panel liquid-crystal displays. New scrap used in the secondary production of indium consists mainly of spent ITO sputtering targets, which are used as ITO source material to produce thin films. Only 30% of the ITO target material is actually deposited onto the substrate when using planar sputtering targets, which are the dominant form of targets. The thin film production efficiency has been greatly improved by the use of rotary sputtering targets. What is left of the target is recycled into indium metal. It is estimated that over 70% of the indium from the starting targets is recovered (Mikolajczak, 2009). Before 1996, only a little part of the indium in ITO manufacturing waste was recycled. Since then, Japan, South Korea and China, where ITO production and thin film manufacturing take place, have installed significant recycling capacities (Lokanc, M. et. al., 2015). Some producers in Belgium, Canada, and Germany also owned indium recycling capacity to a lesser extent (Lokanc, M. et. al., 2015).

Precise data on the amount of secondary indium recovered from scrap are not available, though are estimated to be similar to the quantity of primary production. NREL estimated the production of refined indium from secondary supply reached 610 tonnes in 2013 (Lokanc, M. et. al., 2015).

Previously, the Indium Corporation (Jackson, 2012) estimated that approximatively 1,500 tonnes of refined indium was produced in 2011, including 950 tonnes of recycled indium.

Table 73: Material flows relevant to the EOL-RIR of indium[127], reference year 2012 (BioIntelligence, 2015)

MSA Flow	Value (kg)	Year
B.1.1 Production of primary material as main product in EU sent to processing in EU	0	2012
B.1.2 Production of primary material as by product in EU sent to processing in EU	99,000	2012
C.1.3 Imports to EU of primary material	17,000	2012
C.1.4 Imports to EU of secondary material	8,300	2012
D.1.3 Imports to EU of processed material	61,000	2012
E.1.6 Products at end of life in EU collected for treatment	60,000	2012
F.1.1 Exports from EU of manufactured products at end-of-life	14,000	2012
F.1.2 Imports to EU of manufactured products at end-of-life	3,000	2012
G.1.1 Production of secondary material from post consumer functional recycling in EU sent to processing in EU	200	2012
G.1.2 Production of secondary material from post consumer functional recycling in EU sent to manufacture in EU	0	2012

13.4.3.2 End of life recovery and recycling

Very little old scrap (1%) is recycled worldwide (UNEP, 2011) because of minor indium concentrations in final products, a lack of appropriate technology, or low economic incentives compared to recycling costs (Ylä-Mella and Pongrácz, 2016).

The End-of-life Recycling input rate (Eol-RIR) used in the criticality assessment was set at 0%.

13.5 Other considerations

13.5.1 Environmental and health and safety issues

Indium metal is not subject to registration under the EU REACH regulations (ECHA, 2017). Indium tin oxide and indium phosphide are both subject to registration under the EU REACH regulation (ECHA, 2019a) (ECHA, 2019b).

13.6 Comparison with previous EU assessments

The criticality assessment 2020 has been conducted using the same methodology and assumptions as for the 2017 list. The results of this and earlier assessments are shown in Table 74.

[127] EOL-RIR=(G.1.1+G.1.2)/(B.1.1+B.1.2+C.1.3+D.1.3+C.1.4+G.1.1+G.1.2)

The economic importance of indium has slightly increased between 2012-2016. Since the end-use application of indium remained the same as in the criticality assessment 2017, this increase was a result of the change in the value added of the sectors for which the end-use of indium was relevant.

As it was done in criticality assessment 2017, the supply risk (SR) score is calculated based on the Global HHI only, which reflects the uncertainty about EU production and trade data.

The supply risk score has decreased in comparison with the result from criticality assessment 2017. The lower supply risk value is closely related to the decreasing production share of China in comparison to the period 2010-2014.

Table 74: Economic importance and supply risk results for indium in the assessments of 2011, 2014, 2017, 2020 (European Commission, 2011; European Commission, 2014; European Commission, 2017)

Assessment	2011			2014			2017			2020	
Indicator	EI	SR		EI	SR		EI	SR		EI	SR
Indium	6.7	2.0		5.6	1.8		3.1	2.4		3.25	1.79

13.7 Data Sources

13.7.1 Data sources used in the factsheet

Argusmedia (2019). News – China may acution more indium after Fanya retrial. [online] available at: https://www.argusmedia.com/en/news/1947283-china-may-auction-more-indium-after-fanya-retrial published on 26th of July 2019.

Bio by Deloitte (2015) Study on Data for a Raw Material System Analysis Final report [online] available at: http://cymcdncom/sites/wwwintlmagorg/resource/resmgr/docs/membership_central/newsletter/2016/February/MSA_Final_Report_02pdf

CRM Alliance (2019). Personal communication with Rebecca Lentini after Ad-Hoc-Working-Group meeting in Brussels, June 2019.

DERA Price monitor (2019). [online] Available at: https://www.deutsche-rohstoffagentur.de/SharedDocs/GT_Produkte/Mineral_Rohstoffe/volatilitaetsmonitor_alle-genTab_DE.html?nn=5091242

ECHA (2017). European Chemicals Agency - Registered substances. [online] available at: https://echa.europa.eu/

ECHA (2019a). European Chemicals Agency - Regulatory management option analysis: Indium Tin Oxide. [online] Available at: https://echa.europa.eu/rmoa/-/dislist/details/0b0236e1809b8001

ECHA (2019b). European Chemicals Agency - Substance information: Indium phosphide. [online] Available at: https://echa.europa.eu/substance-information/-/substanceinfo/100.040.856

European Commission (2010). Critical raw materials for the EU. [online] Available at: https://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical_en

European Commission (2014). Report on Critical Raw Materials for the EU. Non-Critical Raw Materials Profiles [online] Brussels European Commission, Available at: http://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical/

European Commission (2017). Critical raw materials for the EU. [online] Available at: https://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical_en

Eurostat (2019)a. International Trade Easy Comext Database [online] Available at: http://epp.eurostat.ec.europa.eu/newxtweb/

Eurostat (2019)b. Annual detailed enterprise statistics for industry (NACE Rev. 2, B-E). [online] Available at: http://ec.europa.eu/eurostat/en/web/products-datasets/-/SBS_NA_IND_R2

Indium Corporation (2013). The Indium Market. [online] Available at: http://www.etf.com/sections/features-and-news/4864-indium-at-your-fingertips-the-go-to-minor-metal-for-flat-panel-displays?nopaging=1

Jackson, W (2012) The Future of Indium Supply and ITO Indium Corporation Association of International Metallizers, Coaters and Laminators (AIMCAL) Web Coating and Handling Conference, Myrtle Beach, South Carolina. [online] available at: http://wwwaimcalorg/uploads/4/6/6/9/46695933/jackson_prespdf

Ladenberger, A., Demetriades, A., Reimann, C., Birke, M., Sadeghi, M., Uhlbäck, J., Zomeni, Z. (2015). GEMAS: Indium in agricultural and grazing land soil of Europe - Its source and geochemical distribution patterns Journal of Geochemical Exploration, 154, 61-80. [online] available at: DOI: 101016/jgexplo201411020

Lauri, Laura (GTK), Teresa Brown, Gus Gunn (BGS), Per Kalvig (GEUS), Henrike Sievers (BGR). (2018). SCRREEN D3.1. Identification and quantification of primary CRM resources in Europe.

Lokanc, M., Eggert, R. and Redlinger, M. (2015). The Availability of Indium: The Present, Medium Term, and Long Term National Renewable Energy Laboratory (NREL) [online] available at: http://wwwnrelgov/docs/fy16osti/62409pdf

Marketwatch (2019). Press Release: Indium market size share 2019 – global industry analysis. [online] available at https://www.marketwatch.com/press-release/indium-market-size-share-2019-global-industry-analysis-trends-industry-demand-growth-opportunities-and-forecast-2024-2019-10-18

Mikolajczak, C. (2009) "Availability of Indium and Gallium" Indium Corporation of America [online] available at: wwwcommodityintelligencecom/images/2010/jan/11%20jan/availability_of_indium_and_galliumwhite_papermikolajczak_sept09pdf

Minerals4EU (2019). European Minerals Yearbook. [online] Available at: http://minerals4eu.brgm-rec.fr/m4eu-yearbook/theme_selection.html

Monnet, A., Abderrahim, A.A. (2018). Report on major trends affecting future demand for critical raw materials. SCRREEN D2.2. Available online at: http://www.scrreen.eu/wp-content/uploads/2018/07/D2.2-Report-on-major-trends-affecting-future-demand-for-critical-raw-materials.pdf

Nyrstar (2015). 2014 Annual Report [online] available at: http://www.nyrstar.com/investors/en/Pages/reportspresentations.aspx

Pinto ,A, Relvas, J.M.R.S., Carvalho, J.R.S., Liu ,Y., Pacheco, N., Pinto, F., Fonseca, R. (2014). High-Tech Metals in the zinc-rich massive ores of the Neves Corvo Deposit Comunicações Geológicas, 101, Especial II, pp 825-828.

Rudnick R, Gao S (2014) Composition of the continental crust. In: Holland H, Turekian K (eds) Treatise on geochemistry, 2nd edn. Elsevier, Oxford, pp 1–51

Schwarz-Schampera, U. (2014) Indium, pp 204–229, *in* Gunn, G (Ed) (2014) Critical Metals Handbook John Wiley & Sons Ltd, Chichester, UK, p454.

SCRREEN workshop. (2019). "Validation Workshop on Critical Raw Materials, 10-12 September 2019, Thon Hotel Brussels City Centre."

Umicore (2019). Minor metal products – Indium. [online] available at https://pmr.umicore.com/en/metals-products/minor-metals/ access date: 20-11-2019

UNEP (2011). Metal Recycling - Opportunities, limits, infrastructure. A Report of the Working Group on the Global Metal Flows to the International Resource Panel. [online] Available at: http://www.unep.org/resourcepanel/publications/metalrecycling/tabid/106143/default.aspx

USGS (2012). Mineral Commodity Summaries. Zinc. [online] Available at: https://minerals.usgs.gov/minerals/pubs/commodity/zinc/mcs-2012-zinc.pdf

USGS (2016a). Mineral Commodity Summaries. Indium. [online] Available at: https://mineralsusgsgov/minerals/pubs/commodity/indium/mcs-2016-indiupdf

USGS (2016b). Mineral Yearbook. Indium. [online] Available at: https://prd-wret.s3-us-west-2.amazonaws.com/assets/palladium/production/atoms/files/myb1-2016-indium.pdf

USGS (2019). Mineral Commodity Summaries. Indium. [online] Available at: https://mineralsusgsgov/minerals/pubs/commodity/indium/mcs-2019-indiupdf

Vulcan, T. (2013) Indium at your fingertips, the go-to minor metal for flat-panel displays [online] available at: http://wwwetfcom/sections/features-and-news/4864-indium-at-your-fingertips-the-go-to-minor-metal-for-flat-panel-displays

World Mining Data (WMD) (2019). Bundesministerium für Wissenschaft, Forschung und Wirtschaft. Austrian Federal Ministry of Science, Research and Economy [online] Available at: http://www.en.bmwfw.gv.at/Energy/WorldMiningData/Seiten/default.aspx

Ylä-Mella, J and Pongrácz, E (2016) Drivers and Constraints of Critical Materials Recycling: The Case of Indium Resources 2016, 5, 34 doi:103390/resources5040034

13.7.2Data sources used in the criticality assessment

The global supply figure from was an average for 2013-2016, since the data was not available before 2013 in World Mining Data.

Bio by Deloitte (2015) Study on Data for a Raw Material System Analysis Final report [online] available at: http://cymcdncom/sites/wwwintlmagorg/resource/resmgr/docs/membership_central/newsletter/2016/February/MSA_Final_Report_02.pdf

European Commission (2016). DG Trade. Agreements [online] Available at: http://ec.europa.eu/trade/policy/countries-and-regions/agreements/

European Commission (2017). Critical raw materials for the EU. [online] Available at: https://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical_en

Eurostat (2019)a. International Trade Easy Comext Database [online] Available at: http://epp.eurostat.ec.europa.eu/newxtweb/

Eurostat (2019)b. Annual detailed enterprise statistics for industry (NACE Rev. 2, B-E). [online] Available at: http://ec.europa.eu/eurostat/en/web/products-datasets/-/SBS_NA_IND_R2

Indium Corporation (2013). The Indium Market. [online] Available at: http://www.etf.com/sections/features-and-news/4864-indium-at-your-fingertips-the-go-to-minor-metal-for-flat-panel-displays?nopaging=1

OECD (2019). Export restrictions on Industrial Raw Materials. [online] Available at: http://qdd.oecd.org/table.aspx?Subject=ExportRestrictions_IndustrialRawMaterials [Accessed September 2019]

SCRREEN workshop. (2019). "Validation Workshop on Critical Raw Materials, 10-12 September 2019, Thon Hotel Brussels City Centre."

Tercero Espinoza, L., Hummen, T., Brunot, A., Hovestad, A., Pena Garay, I., Velte, D., Smuk, L., Todorovic, J., van der Eijk, C. and Joce, C. 2013. "Critical Raw Materials Substitution Profiles. September 2013 Revised May 2015. CRM_InnoNet Available At:" http://www.criticalrawmaterials.eu/wp-content/uploads/D3.3-Raw-Materials-Profiles-final-submitted-document.pdf.

UNEP (2011). Metal Recycling - Opportunities, limits, infrastructure. A Report of the Working Group on the Global Metal Flows to the International Resource Panel. [online] Available at: http://www.unep.org/resourcepanel/publications/metalrecycling/tabid/106143/default.aspx

USGS (2019). Mineral Commodity Summaries. Indium. [online] Available at: https://mineralsusgsgov/minerals/pubs/commodity/indium/mcs-2019-indiupdf

World Mining Data (WMD) (2019). Bundesministerium für Wissenschaft, Forschung und Wirtschaft. Austrian Federal Ministry of Science, Research and Economy [online] Available at: http://www.en.bmwfw.gv.at/Energy/WorldMiningData/Seiten/default.aspx

13.8 Acknowledgments

This factsheet was prepared by the JRC. The authors would like to thank SCRREEN expert network, the EC Ad Hoc Working Group on Critical Raw Materials and all other relevant stakeholders for their contributions to the preparation of this Factsheet.