SCRREEN2

This project has received funding from the European

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Start date: 2020-11-01 Duration: 36 Months

FACTSHEETS UPDATES **BASED ON THE EU FACTSHEETS 2020**

LEAD

AUTHOR(S):

TABLE DES MATIÈRES

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LEAD

OVERVIEW

Lead (Pb) is a soft, malleable grey metal with a high density of 11.3 g/cm^3, a poor electrical conductivity and a good resistance to corrosion to most acids, including sulphuric and chromic acids. Lead is usually extracted together with zinc, silver and copper. For the purpose of this assessment lead is analysed at both extraction and processing stages.

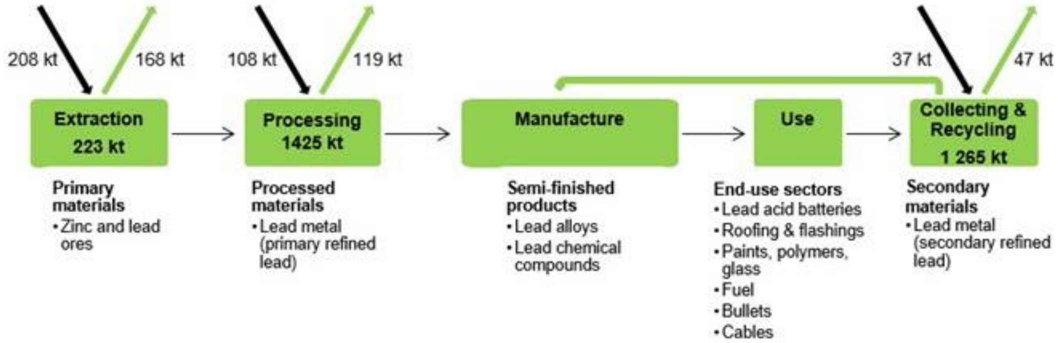

Figure 1. Simplified value chain for lead in the EU[1]

Table 1. Lead supply and demand (extraction) in metric tonnes, 2016-2020 average

Global production	Global Producers	EU consumption	EU Share	EU Suppliers	Import reliance
4,635,377	China 43% Australia 10% US 6% Peru 6% Mexico 6% Russia 4% India 4%	270,889	5.8%	North Macedonia 18% USA 16% Peru 15% Mexico 16% Morocco 8% Argentina 7% Bolivia 5%	21%

Table 2. Lead supply and demand (processing) in metric tonnes, 2016-2020 average

Global production	Global Producers	EU consumption	EU Share	EU Suppliers	Import reliance
11,983,281	China 49% United States 11% Korea, South 8% India 6% Mexico 4% United Kingdom 3%	1,513,165	12.6%	United Kingdom 47% Russia 11% Lebanon 10% Kazakhstan 7% Korea, South 7% Ukraine 6%	6%

[1] JRC elaboration on multiple sources (see next sections)

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Prices: Lead prices have traditionally been based on the LME (London Metals Exchange). The price of lead is driven mostly by Chinese demand for automotive and traction batteries, power storage devices and global stocks. Average annual prices (from 2012 to 2014) which were slightly above the USD 2,000 per tonne mark declined in 2015 amid weak demand, before strongly recovering in 2016 as concerns on primary supply issues rose following the closure of the Century mine in Australia and Lisheen mine in Ireland.

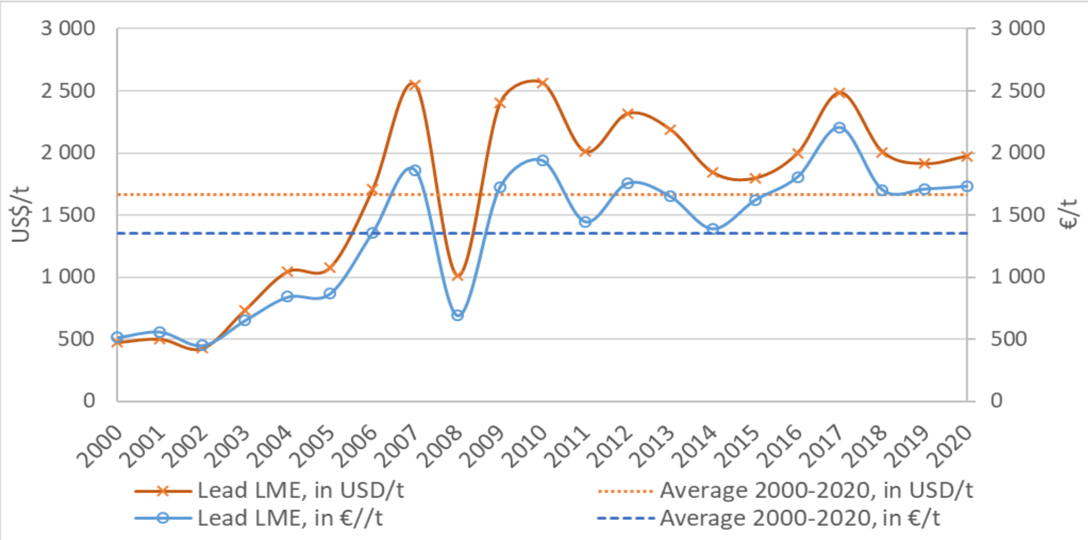

Figure 2. Annual average price of lead between 2000 and 2020 (USGS, 2021)[2].

Primary supply: Primary lead ore is extracted from mines in about 48 countries (BGS, 2022). The average annual global mine production is 4,635 kt lead over the period 2016-2020. The domestic production of refined lead amounted to 1,675 kt per year (average 2016-2020), with Germany (334 kt) and UK (308 kt) accounting for ~37% of this production. With Brexit, EU27 domestic lead production decreased by 18 %.

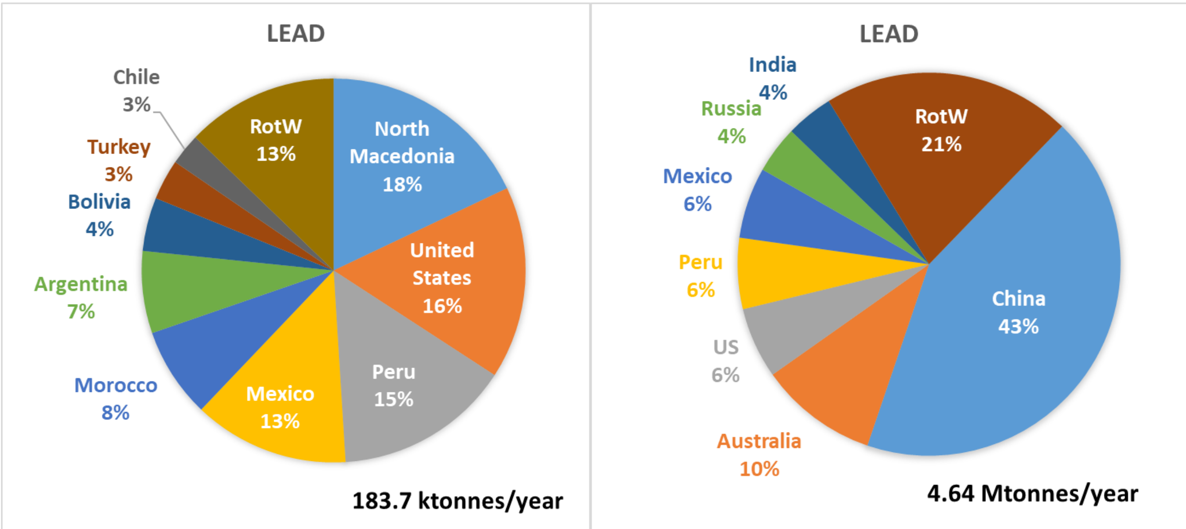

Figure 3. EU sourcing of lead and global mine production (update)

[2] Values in €/kg are converted from original data in US$/kg by using the annual average Euro foreign exchange reference rates from the European Central Bank (https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/eurofxref-graph-usd.en.html)

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Secondary supply: Lead has one of the highest recycling rates of all materials in common use to-date. More refined lead is produced by recycling than from mines. World annual secondary lead production amounted to 6,300 kt over the period 2012-2016 (57% of the total metal output) (ILZSG, 2017). Secondary refined lead production represented 83% of the EU27 metal production in 2021 (ILZSG, 2021). Most of this production results from the processing of waste generated in the EU and from a small amount of imported scraps.

Uses: The major application of lead is in batteries, while there is a variety of minor applications.

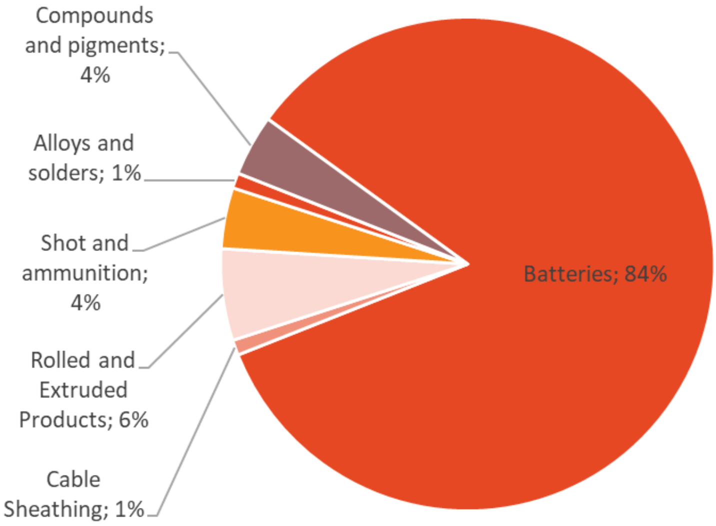

Figure 4: EU uses of lead

Substitution: Lead-acid batteries used to be the predominant technology option in automotive industry, due to their low cost, reliability in a wide range of climates and well-established supply chain. Lithium-ion batteries (LIB) are increasingly replacing lead-acid batteries for many applications.

Table 3. Uses and possible substitutes

Use	Percentage*	Substitutes	Sub share	Cost	Performance
Batteries	84%	Li-batteries	35%	Slightly higher costs	Similar
		NiCd	1%	Very high costs	Similar
		NiMH	1%	Very high costs	Similar

*Estimated end use shares of lead based on ILZSG (2008) (European Commission, 2020) and outputs of SCRREEN Experts Validation Workshop (2022)

Other issues: Exposure to lead through ingestion or inhalation may result in different types of physiological damages e.g. neurological deficits, risk of anaemia, potential disruption in cell growth and maturation, kidney diseases, damages to fertility or to the unborn child, and carcinogenic (ILO, 2011). Moreover, lead is also very toxic to aquatic life (ECHA, 2023). The main route of exposure to lead in an industrial context is through inhalation of dust/powder particles generated in the working atmosphere (e.g. vapours/fumes occurring during lead metal heating) (IFA, 2023). Lead is generally exploited from sulfidic deposits, which implies a potential risk of acid mine drainage[3] from the generated wastes (German Environmental Agency, 2020).

[3] Formation and runoff of acidic water that is rich in heavy metals

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MARKET ANALYSIS, TRADE AND PRICES

GLOBAL MARKET

Table 4. Lead supply and demand (extraction) in metric tonnes, 2016-2020 average

Global production	Global Producers	EU consumption	EU Share	EU Suppliers	Import reliance
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Table 5. Lead supply and demand (processing) in metric tonnes, 2016-2020 average

Global production	Global Producers	EU consumption	EU Share	EU Suppliers	Import reliance
11,983,281	China 49% United States 11% Korea, South 8% India 6% Mexico 4% United Kingdom 3%	1,513,165	12.6%	United Kingdom 47% Russia 11% Lebanon 10% Kazakhstan 7% Korea, South 7% Ukraine 6%	6%

Lead is extracted at 4.6 million tonnes per years globally. China, followed by Australia and the US, were the biggest among the list of countries by lead production (extraction). The three lead producing countries together accounted for 59% of the global lead output. The lead market is partially fragmented in nature, with no major player having a clear dominance over the market.

Lead is traded on the major exchanges around the world, including the London Metals Exchange (LME) and the Shanghai Metal Exchange (SHME). The LME trades a contract on ingots of lead that are 99.97% pure. Each contract represents 25 tonnes of lead and is quoted in US dollars.

Some of the key players in the market include Glencore, Korea Zinc, Teck Resources Limited, Canada Metal North America Ltd, and Gravita Metals, among others (Mordor Intelligence, 2022). Glencore was the largest producer of lead in 2021 with an attributable production of around 283 kilotonnes ((S&P Global, 2022). Reserves are important in Australia (35,000 tonnes) and China (18,000 tonnes). (USGS, 2022).Reserves are important in Australia (35,000 tonnes) and China (18,000 tonnes). (USGS, 2022).

Lead is mainly used for the manufacturing of lead-acid batteries, which accounted for 86% of the metal consumption worldwide in 2019, according to Statista. The other end-uses of lead are for rolled and extruded products, alloy, solder, lead oxides, shot and ammunition.

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Lead-acid batteries are estimated to face a long-term decline in demand due to the replacement of thermal cars by electric vehicles. Global refined lead production in 2021 was estimated to increase by 4.4%, and metal consumption was deemed to increase by 5.5% (USGS, 2022).

In cable covering and cans, lead was substituted by plastic. In the electronics industry, lead solders were substituted, and flat-panel displays did not require lead shielding. In wheel weights, steel and zinc can substitute lead (USGS, 2022).

EU TRADE

Lead metal is assessed at Mining and processing/refining stage. Table 6 lists relevant Eurostat CN trade codes.

Table 6. Relevant Eurostat CN trade codes for Lead metal

Mining		Processing/refining	
CN trade code	**title**	**CN trade code**	**title**
26070000	Lead ores and concentrates	78011000	Unwrought lead, refined

The listed CN codes that referring to Lead are: 2607- Lead ores and concentrates, 2824- Lead oxide, red lead and orange lead, 283670- Lead carbonates, 78- Lead and lead articles.

Figure 5 shows the import and export trend of lead ores and concentrates in years 2000-2021. The EU exports and import had an increasing and decreasing trend with so many fluctuations, respectively. The EU import declined from 455,613 tonnes in 2000 to 270,692 tonnes in 2021 while the EU export raised from 167,331 tonnes in 2000 to 179,764 tonnes in 2021.

Figure 6 illustrates the share of import in EU for lead ores and concentrates from various countries. The main import partners of EU are Australia (16%), Peru (14%), North Macedonia (13%), US (11%) and Morocco (7%). The import from Australia decreased and stopped from 2019.

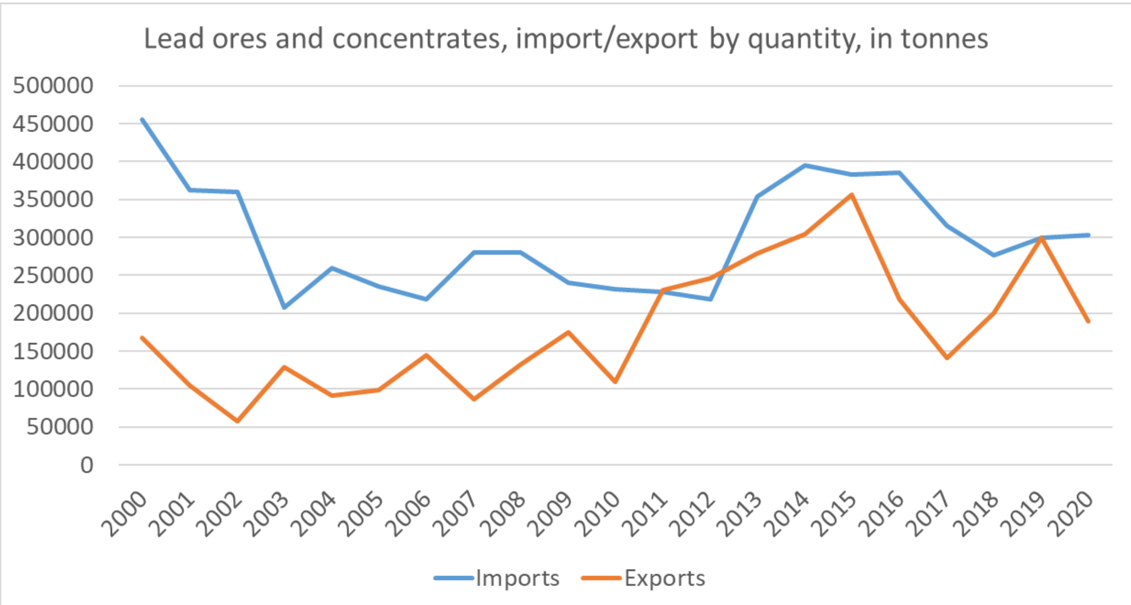

Figure 5. EU trade flows of lead ores and concentrates (CN 26070000) from 2000 to 2021 (Eurostat, 2022)

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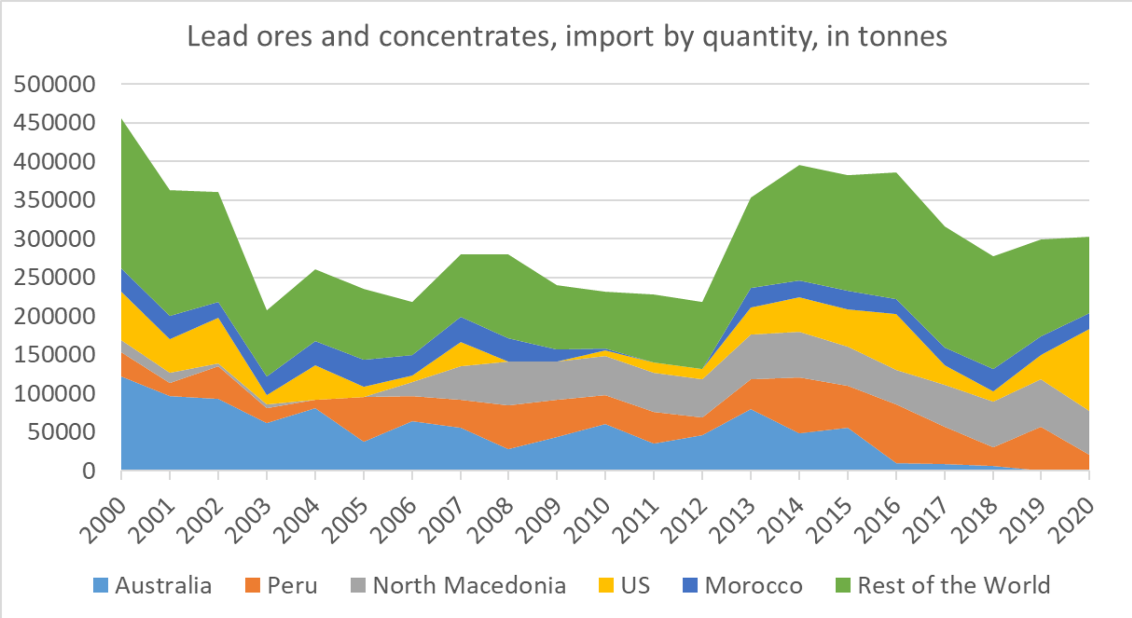

Figure 6. EU imports of lead ores and concentrates (CN 26070000) by country from 2000 to 2021 (Eurostat, 2022)

Figure 7 shows the import and export trend of Unwrought lead, refined during the year 2000-2021. The EU is a net importer of lead. The EU imports had some fluctuations during years 2000-2020 with a maximum at 338 ktonnes in 2003 and a minimum at 89 ktonnes in 2020. The Eu exports had also some fluctuations with a maximum at 183ktonnes in 2009 and a minimum at 45ktonnes in 2002. Imports were higher than exports but between 2009 and 2015 (with the exception of 2011). The export declined from 183 ktonnes in 2000 to 64 ktonnes in 2020.

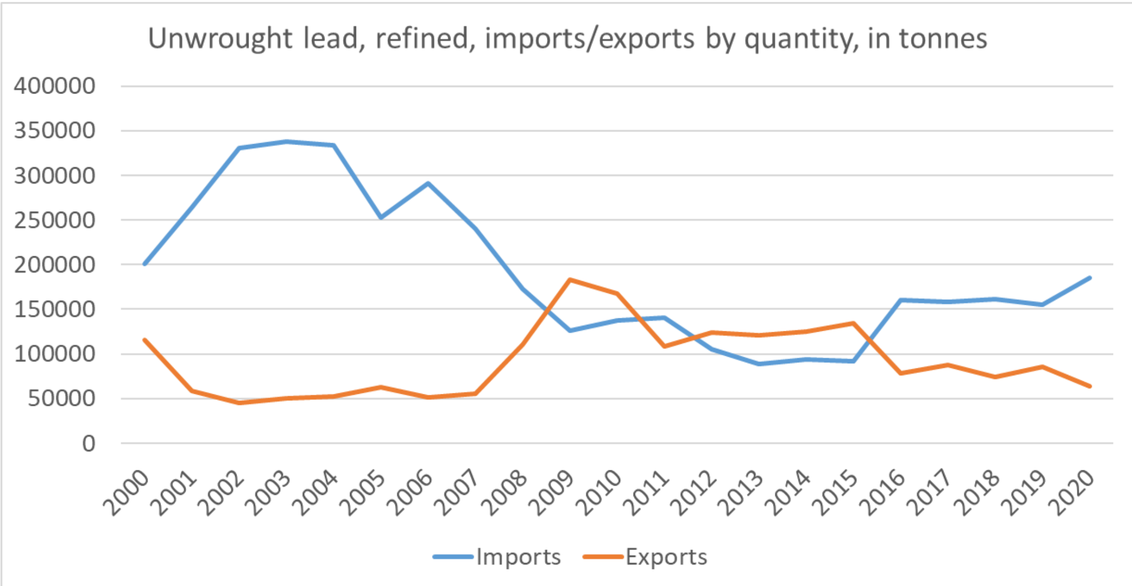

Figure 7. EU Trade flows of lead and lead articles (CN 78011000) from 2000 to 2021 (Eurostat, 2022)

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Figure 8 illustrates the share of import in EU for Unwrought lead, refined from various countries. The import of Unwrought lead, refined in the past two decades (2000-2020) fluctuated rather greatly. UK, Russia, Lebanon and Kazakhstan were the competing major suppliers to the EU.Imports from Russia increased from 7.9 ktonnes in 2000 to 25.7 ktonnes in 2016 before decreasing between 2016 and 2020 down to 13.7 ktonnes.

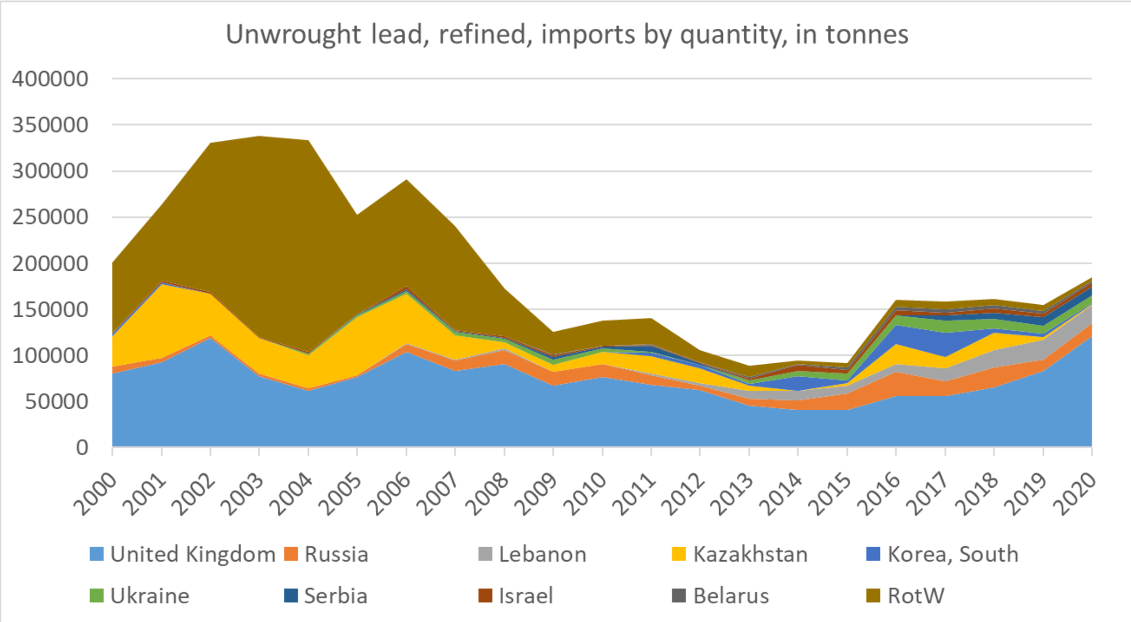

Figure 8. EU imports of lead and lead articles (CN 78011000) by country from 2000 to 2021 (Eurostat, 2022)

3.3. PRICE AND PRICE VOLATILITY

Lead prices have traditionally been based on the LME (London Metals Exchange). The price of lead is driven mostly by Chinese demand for automotive and traction batteries, power storage devices and global stocks. In addition, other factors such as global stock, demand outlook, competing technologies and health concerns can influence the lead price.

Average annual prices (from 2012 to 2014) which were slightly above the USD 2,000 per tonne mark declined in 2015 amid weak demand, before strongly recovering in 2016 as concerns on primary supply issues rose following the closure of the Century mine in Australia and Lisheen mine in Ireland. After reaching a high point in February 2018 at USD 2,682 per tonne, lead lost around 25% of its value through 2018 as market became better supplied. Even with a decrease in sales in the automotive industry and the overall slowdown in the manufacturing sector, the lead price remained relatively resilient in 2019. Its strength largely reflects production disruptions at Australia's Port Pirie smelter and at mines such as Peñasquito in Mexico and San Cristobal in Bolivia (Fastmarkets, 2019).

The COVID-19 lockdowns and containment measures impacted prices negatively during the first part of 2020. Lead prices rebounded in the second half as the demand grew stronger and supply worries increased due to mine production disruptions, particularly in South America (Barrera, 2021). Lead prices had a strong start to 2021 as they recovered from the uncertainty caused by the COVID-19 pandemic in 2020. However, the lead market remained mostly volatile. Although volatility was high, prices reached their highest level in more than three years (Barrera, 2022).

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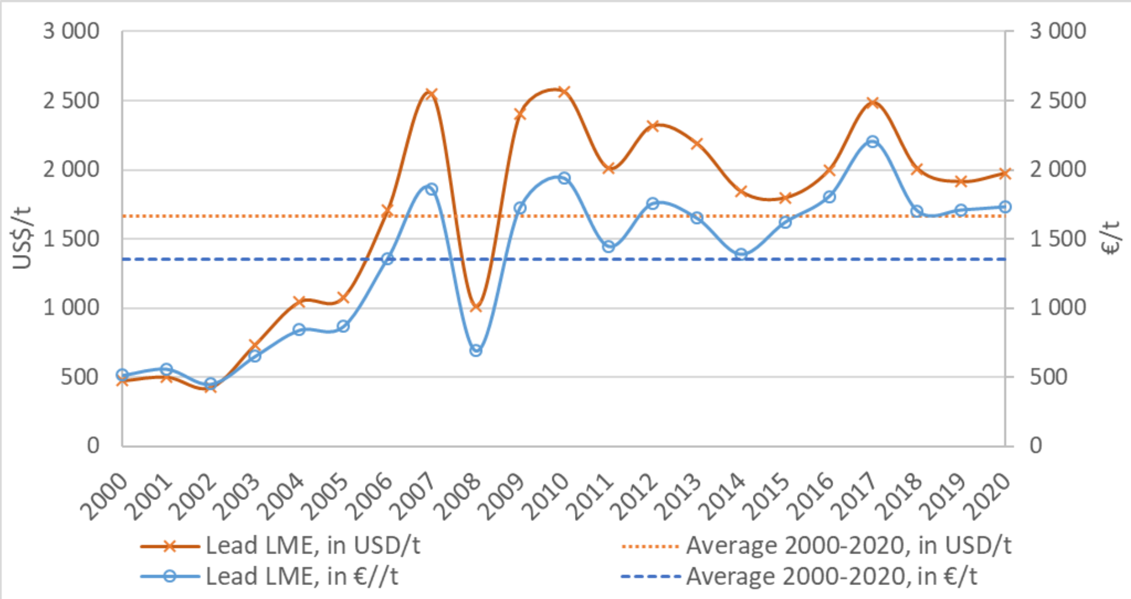

Figure 9. Annual average price of lead LME between 2000 and 2020, in US$/t and €/t[4]. Dash lines indicates average price for 2000-2020 (S&P Global, 2022)

OUTLOOK FOR SUPPLY AND DEMAND

The lead market is projected to register a CAGR of over 5% during the period 2021-2026. The market continues to be negatively impacted by the COVID-19 pandemic (Mordor Intelligence, 2022). With China being the most significant consumer of refined lead, COVID-19 lockdowns in the financial hub of Shanghai in 2022 harshly impacted demand and market sentiment for all industrial metals which caused prices to decline. The strict COVID-19 policies across China threaten to diminish consumer spending and construction activity thus severely dampening the demand outlook for lead (Wong, 2022). Moreover, the World Bank predicts recessions across many countries and a contraction in global economic growth which could reduce the demand for lead (World Bank, 2022).

Lead's main use is for lead-acid batteries which are used to power internal combustion engines (ICE). The uptake of electric vehicles (EV) has been rising while the sales of ICE vehicles has been slowing down due to decarbonization efforts. Various analysts believe that the decarbonisation trend is likely to reduce lead demand in the longer term (Wong, 2022). The World Bank predicts that global lead demand will rise in the medium term "*due to steady new vehicle and replacement battery use, as well as the utilisation of lead batteries in EVs for auxiliary functions*" (World Bank, 2022). Fitch Solutions believes that the global surplus of refined lead that was generated over the Covid-19 pandemic will slowly tighten in the coming years.

[4] Values in €/kg are converted from original data in US$/kg by using the annual average Euro foreign exchange reference rates from the European Central Bank (https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/eurofxref-graph-usd.en.html)

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Growth in production will also be restricted by environmental regulations, especially in China (Fitch Solutions, 2022). Statista predicts the average lead prices to be at USD 2,100 per tonne in 2022, USD 2,000 per tonne in 2023, USD 2,008 per tonne in 2024, and USD 2,016 per tonne in 2025. Analysts have refrained from providing longer term forecasts due to the volatility and uncertainty caused by the Ukraine-Russia war (Statista, 2022).

DEMAND

GLOBAL AND EU DEMAND AND CONSUMPTION

Lead extraction stage EU consumption is presented by HS code CN 26070000 Lead ores and concentrates. Import and export data is extracted from Eurostat Comext (2022). Production data is extracted from BGS (2022).

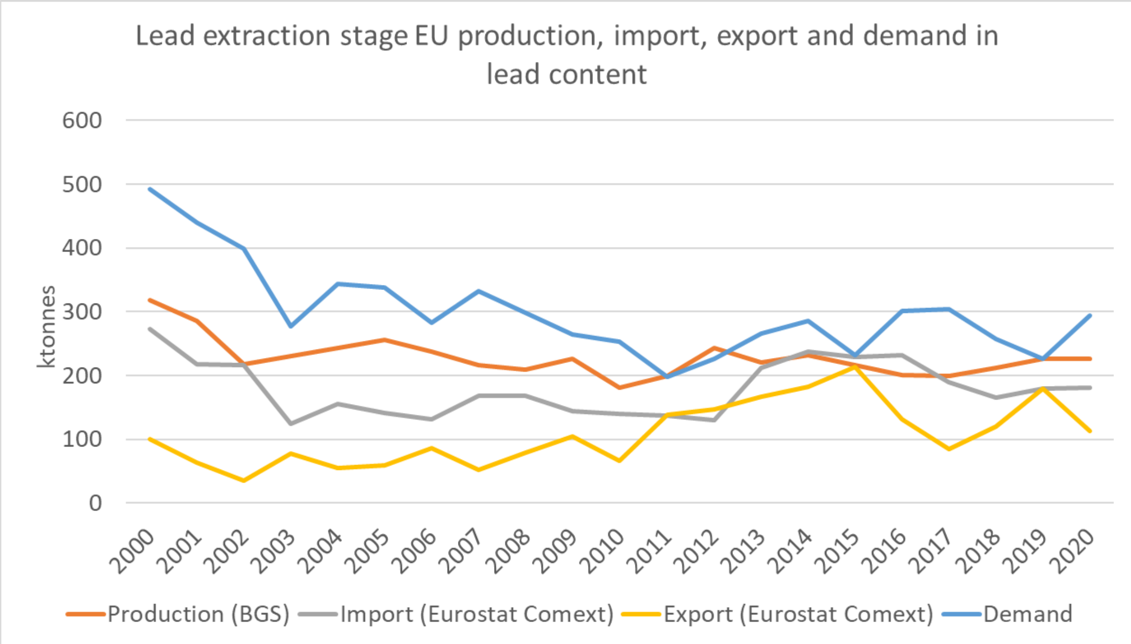

Figure 9. Lead (CN 26070000) extraction stage apparent EU consumption. Production data is available from BGS (2022). Consumption is calculated in lead content (EU production+import-export).

Lead processing stage (lead metal) EU consumption is presented by HS code CN 78011000 - Unwrought lead, refined. Import and export data is extracted from Eurostat Comext (2022). Production data is extracted from BGS (2022).

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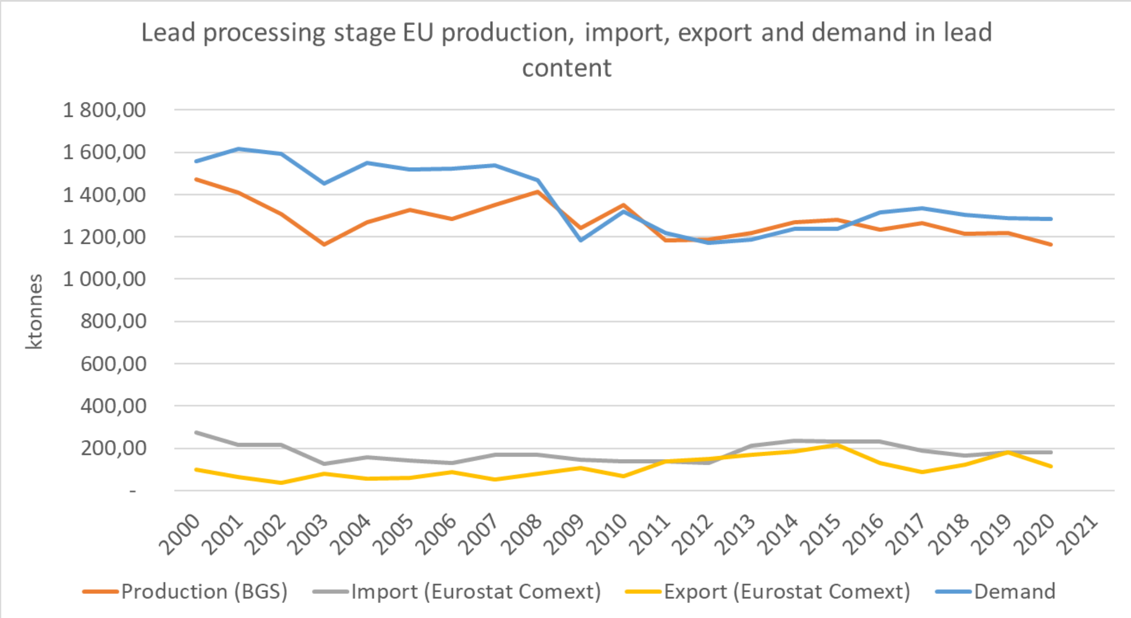

Figure 10. Lead (CN 78011000) processing stage apparent EU consumption. Production data is available from BGS (2022). Consumption is calculated in lead content (EU production+import-export).

Average import reliance of lead at extraction stage is 21 % and at processing stage 6 % for 2016-2020.

GLOBAL AND EU USES AND END-USES

The major application of lead is in batteries, while there is a variety of minor applications described below.

Up to 2005, there was consistent and well-founded reporting of the principal first uses of lead (ILZSG, 2008). The contact to ILZSG, the institution which provided this data, showed, that countries stopped reporting the production of lead first uses. Therefore, here is no contemporary, comprehensive data on the use structure of lead.

Expert opinions indicate that the use shares of lead remained relatively constant within the past 20 years (CRM experts, 2022; European Commission, 2020). Based on that, the best available estimation for the end use shares of lead is shown in Figure 11.

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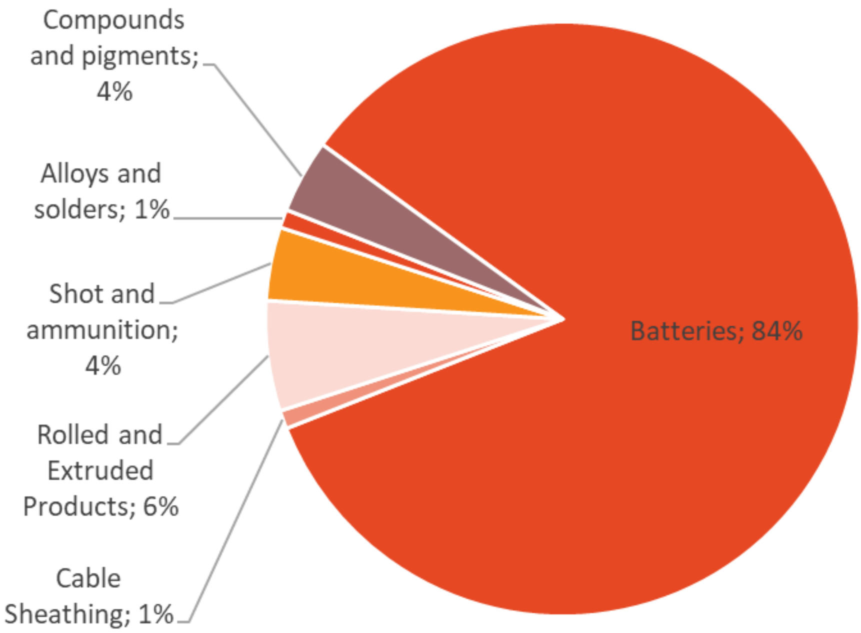

Figure 11. Estimated end use shares of lead based on ILZSG (2008) (European Commission, 2020).

Relevant industry sectors are described using the NACE sector codes as listed in Table 7 and illustrated in Figure 12 (Eurostat, 2021).

Table 7. Lead applications, 2-digit and examples of associated 4-digit NACE sectors, and value-added per sector for 2018 (* for 2014) (Eurostat, 2021).

Applications	2-digit NACE sector	Value added of NACE 2 sector (M€)	4-digit CPA
Batteries	C27 - Manufacture of electrical equipment	98,417	C27.20 – Manufacture of batteries and accumulators
Rolled and extruded products	C24 - Manufacture of basic metals	71,391	C24.4.3 Lead, zinc and tin production
Lead compounds	C20 - Manufacture of chemicals and chemical products	117,093*	C20.1.6 - Manufacture of plastics in primary forms.
Shot/ammunition	C25 - Manufacture of fabricated metal products, except machinery and equipment	183,016	C25.4.0 - Manufacture of weapons and ammunition
Cable sheathing	C27 - Manufacture of electrical equipment	98,417	C27.3.2 - Manufacture of other electronic and electric wires and cables
Alloys and solders	C24 - Manufacture of basic metals	71,391	C24.4.3 - Lead, zinc and tin production

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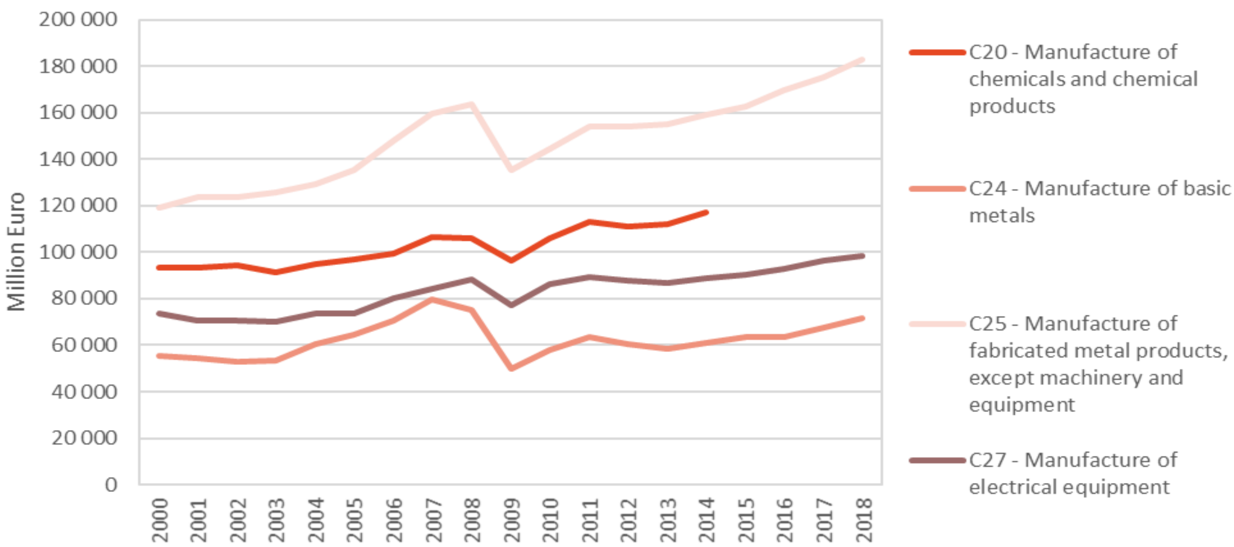

Figure 12. Value added per 2-digit NACE sector over time (Eurostat, 2021).

APPLICATIONS OF LEAD

LEAD-ACID BATTERIES

The largest application for lead is by far the manufacture of lead acid batteries which accounted for about 84 % of the global lead consumption.

Lead-acid technology is used for starting, lighting and ignition (SLI) in conventional combustion engine vehicles and as back-up for uninterruptible power supplies and grid energy storage (European Commission, 2020).

ROLLED AND EXTRUDED LEAD PRODUCTS

Lead is used in the manufacture of rolled and extruded products (lead sheets, wires etc.). Lead sheet is used in the building, construction and chemical industry due to its durability, malleability, high density and corrosion resistance. Sheet is also used as flashings to prevent water penetration, for roofing and cladding; to a lesser degree, as a radiation shielding and sound insulation material; by the chemical industry for the lining of chemical treatment baths, acid plants and storage vessels.

Lead pipes are used for carriage of corrosive chemicals at chemical plants and as “sleeves” to join lead sheathed cables.

LEAD COMPOUNDS

Lead compounds used as stabilisers in PVC have been voluntarily eliminated within the EU under the Vinyl 2010/VinylPlus voluntary commitments of the PVC industry, and their sales ceased in late 2015 (The European council of vinyl manufacturers, 2016; The European stabiliser producers association, 2016).

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Lead based paints and frits are also being phased out in Europe. However, lead-based paints are still widely sold in all developing regions of the world (IPEN, 2016), and their use is limited to a few specific applications (artist paints, some industrial paints) in the rest of the world.

SHOT AND AMMUNITION

Shot lead is an alloy of lead, antimony, and tin.

CABLE SHEATHING

Lead alloys are used as a sheathing material for power cables in the petrochemical industry or undersea and for underground high voltage cables.

ALLOYS AND SOLDERS

Tin-lead alloys are the most widely used soldering alloys. Soft solders are largely lead-tin alloys with or without antimony, while fusible alloys are various combinations of lead, tin, bismuth, cadmium and other low melting point metals.

SUBSTITUTION

The substitutability of lead first uses is summarized in Table 8 and described in more detail below.

Table 8. Substitution options for lead by application.

Use	Percentage*	Substitutes	Sub share	Cost	Performance
Batteries	84%	Li-batteries	35%	Slightly higher costs	Similar
		NiCd	1%	Very high costs	Similar
		NiMH	1%	Very high costs	Similar

*Estimated end use shares of lead based on ILZSG (2008) (European Commission, 2020) and outputs of SCRREEN Experts Validation Workshop (2022)

BATTERIES

Lead-acid batteries used to be the predominant technology option in automotive industry, due to their low cost, reliability in a wide range of climates and well-established supply chain. Lithium-ion batteries (LIB) are increasingly replacing lead-acid batteries for many applications. For example, in Germany in 2021, 9 % of the rechargeable batteries put on the market were lead-acid batteries, while LIBs were predominant with almost 83 % (Stiftung GRS Batterien, 2022). Other commercially available systems include nickel-metal hydride (NiMH) and nickel-cadmium (NiCd) batteries.

ROLLED AND EXTRUDED LEAD PRODUCTS

There are several alternatives to the use of lead in most sheet applications such as galvanized steel, aluminium, copper and non-metallic materials.

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LEAD COMPOUNDS

Lead based PVC stabilisers can be replaced by calcium-based stabilizers (Ca-Zn and Ca-organic). Lead-based stabilisers have been phased out by the PVC industry and the replacement was completed by the end of 2015. Cost-effective non-leaded pigments, driers and anti-corrosive agents have been available for decades (titanium dioxide, organic and inorganic pigments, zinc phosphate primers etc.).

CABLE SHEATHING

Lead free cables have been developed by industry manufacturers. Some of the designs include an inner aluminium polyethylene (AluPE) tape, a high-density polyethylene (HDPE) sheath and a polyamide cover. The advantages of lead-free alternative designs – apart from their non-toxicity- are the lower cable weight and reduced diameters, which can be beneficial in the installation (Nexans, 2016).

ALLOYS

Within the EU, all soldering materials meet European standard's requirements and lead-free solders are compliant with European Directives RoHS and WEEE. Existing exemptions are periodically reviewed. There are several families of tin-based alloys commercially available as lead-free solders which are generally specific to a certain application such as SnAgCu (tin-silver-copper), SnAgCuBi (tin-silver-copper-bismuth), SnIn (tin-indium) alloys etc.

SUPPLY

EU SUPPLY CHAIN

The domestic production of refined lead amounted to 1,675 kt per year (average 2016-2020), with Germany (334 kt) and UK (308 kt) accounting for ~37% of this production. With Brexit, EU27 domestic lead production decreased by 18 %. Secondary refined lead production represented 83% of the EU27 metal production in 2021 (ILZSG, 2021). Most of this production results from the processing of waste generated in the EU and from a small amount of imported scraps.

SUPPLY FROM PRIMARY MATERIALS

GEOLOGY, RESOURCES AND RESERVES OF LEAD

GEOLOGICAL OCCURRENCE:

Lead concentration in the Earth continental upper crust is estimated to be 17 ppm (Rudnick & Gao, 2014), which is relatively low compared to the other base metals.

Lead is mainly extracted as a zinc co-product from two main types of deposits hosted in sedimentary rocks: sedimentary-exhalative (SEDEX) and Carbonate hosted deposits which include Mississippi-valley type (MVT)

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and Irish type carbonate lead zinc deposits. These Pb-Zn deposits which, put together, contain around half of the global resources of lead (Singer, 1995) and dominate world production of lead and zinc. Lead occurs in the form of galena, a sulphide (PbS), in association with sphalerite (ZnS). Silver and barite may also be economically recovered from these deposits. Carbonate replacement deposits (CRD), zinc-lead skarn deposits and volcanogenic massive sulphide deposits (VMS) are also important sources of lead.

SEDEX deposits are hosted in fine grained clastic sediments, mainly shales. Most are large, tabular or stratiform deposits which typically consist of lead and zinc sulphide-rich beds inter-layered with sulphide-poor clastic units. They form from warm brines (100-200C°) discharged on or just below the seafloor, in sedimentary basins in continental rift settings. They include some of the largest lead-zinc deposits in the world, such as McArthur River in Australia and Red Dog in the USA.

MVT deposits are epigenetic stratabound deposits hosted mainly by dolomites and limestones. They form from warm brines with temperatures in the range of 75-200°C (the Irish style tend to have higher temperatures with some data indicating up to 240°C) in carbonate platforms adjacent to cratonic sedimentary basins (e.g. Viburnum trend, USA; Silesia, Poland). The mineralization occurs as replacement of the carbonate rocks and as open-space fill (Paradis et al, 2007; Leach et al., 2010).

Carbonate-replacement deposits (CRD) and zinc-lead skarn deposits (e.g. Groundhog, USA; Bismark, Mexico) are hosted by carbonate rocks (limestones, dolomites, calcareous clastic sediments). They form by reaction of high temperature hydrothermal fluids (>>250°C) with the carbonate rocks, in the vicinity of igneous intrusions. CRD deposits occur as massive lenses, pods, and pipes (mantos or chimneys) (Hammarstrom, 2002).

Volcanogenic Massive Sulphide Deposits (VMS) are hosted either in volcanic or in sedimentary rocks and occur as lenses of polymetallic massive sulphide. VMS deposits form on, and immediately below the seafloor, by the discharge of a high temperature, hydrothermal fluids in submarine volcanic environments. They also are significant sources for cobalt, tin, selenium, Manganese, cadmium, indium, bismuth, tellurium, gallium, and germanium.

GLOBAL RESOURCES AND RESERVES*:*

The USGS (2022) estimated the world identified lead resources at more than 2,000 Mt[1]. Global reserves of lead at the end of 2018 were estimated at around 90 Mt (USGS, 2022), with Australia and China accounting for half of the global total (Table 1). Mudd et al. (2017) assessed the known world lead-zinc mineral resources. In this study it is indicated that at least 226 Mt of lead were present at that time within 851 individual mineral deposits and mine waste projects from 67 countries, at an average grade of 0.44% lead.

Table 9. Global reserves of primary lead in year 2022 (USGS, 2022).

country	reserves[tons]	country	reserves[tons]	country	reserves[tons]
Australia	37,000	UnitedStates	5,000	Bolivia	1,600
China	18,000	Russia	4,000	Sweden	1,100
Peru	6,400	India	2,500	Turkey	860
Mexico	5,600	Kazakhstan	2,000	Othercountries	5,900
Worldtotal(rounded)	90,000				

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Table 10. Reserve data for the EU compiled in the European Minerals Yearbook (Minerals4EU, 2019)

Country	Reporting code	Quantity	Unit	Grade	Code Resource Type
Czech Republic	Nat. rep. code	0.2	Mt	0.67%	Potentially economic
		0.8	Mt	-	P1
		5.3	Mt	-	P2
France	None	0.8	Mt	Metal content	Historic resource estimate
Greece	USGS	35.3	Mt	4.12%	Measured
Hungary	Russian Classification	0	Mt	-	A
		0.5	Mt	-	B
		4	Mt	-	C2
Ireland	JORC	57.4	Mt	1.28%	Measured, Indicated & Inferred
Italy	None	0.1	Mt	-	Sub-economic
Poland	Nat. rep. code	1.3	Mt	0.08	A+B+C1
		0	Mt	0.02	C2 + D
		1.3	Mt	0.07	Total
		0.6	Mt	1.84	A+B+C1
		0.7	Mt	1.78	C2 + D
		1.3	Mt	1.8	Total
Portugal	NI43-101	33.9	Mt	1.40%	Measured
		112.2	Mt	0.90%	Indicated
		47.2	Mt	0.64%	Inferred
Slovakia	None	0	Mt	1.17%	Probable (Z2)
		1.6	Mt	1.17%	Anticipated (Z3)
Spain	NI43-101	10.8	Mt	0.01%	Measured
Sweden	JORC	0.5	Mt	0.40%	Measured
		3	Mt	2.05%	Indicated
		1.5	Mt	1.60%	Inferred
	NI43-101	8.5	Mt	4.80%	Measured
		6.4	Mt	4.20%	Indicated
		5	Mt	3.20%	Inferred
	FRB- standard	5.2	Mt	0.91%	Measured
		26.2	Mt	1.23%	Indicated
		39.5	Mt	1.26%	Inferred
United Kingdom	JORC	2.1	Mt	2.18%	Indicated
		4.1	Mt	1.20%	Inferred

Resource data for countries in Europe are available in Minerals4EU (see Table 2). In Poland, the anticipated economic resources of Zn-Pb ores (all in in the Silesian-Cracow region) amounted to 90.98 million tonnes of ore yielding 1.43 Mt of lead (Polish Geological Institute 2022). The Pallas Green Project in Ireland is one of the

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largest undeveloped zinc-lead deposits in the world. Inferred mineral resources (JORC) are 45.1 Mt at a grade of 7% zinc and 1% lead, as at 31 December 2018 (according to Glencore Plc).

The Pallas Green Project in Ireland is one of the largest undeveloped zinc-lead deposits in the world. Glencore estimated inferred mineral resources (JORC) to be 45.1 Mt at a grade of 7% zinc and 1% lead, as at 31 December 2018.

4.2.2 WORLD AND EU MINE PRODUCTION

Primary lead ore is extracted from mines in about 48 countries (BGS, 2022). The average annual global mine production is 4,635 kt lead over the period 2016-2020.

In the Asia-Pacific region, the largest active lead mines are the Sindesar Khurd and Zawar mines in India and the Fankou mine in China (GlobalData, 2022). Largest mines in Eurasian region are the Zhairemsky and Akzhal Zinc Lead mines (Kazakhstan) and the Kyzyl-Tash Turk mine (Russia) (GlobalData, 2022). In Europe the three largest active mines are Garpenberg and Zinkgruvan Mines in Sweden, and Sasa Zinc & Lead Mine in North Macedonia (GlobalData, 2022).

Over the period 2016-2020, the EU produced in average 213 kt of lead concentrates per year (in 2020: 226 kt). Sweden (69.1 kt) and Poland (68.4 kt) accounted for up to 58% of the EU production (Figure 13). Polish lead-zinc production from the Klucze I, Olkusz and Pomorzany deposits in the Olkusz region was termined in 2020, resulting in no mining of lead-zinc ore in Poland in 2021 (Polish Geological Institute, 2022). The Garpenberg and Zinkgruvan mines produced most of the lead extracted in Sweden. Significant other production is in Bulgaria (17.4), Ireland (16.8 kt), Portugal (16.7 kt), and Greece (15.3 kt). The domestic production accounted for 5% of world production.

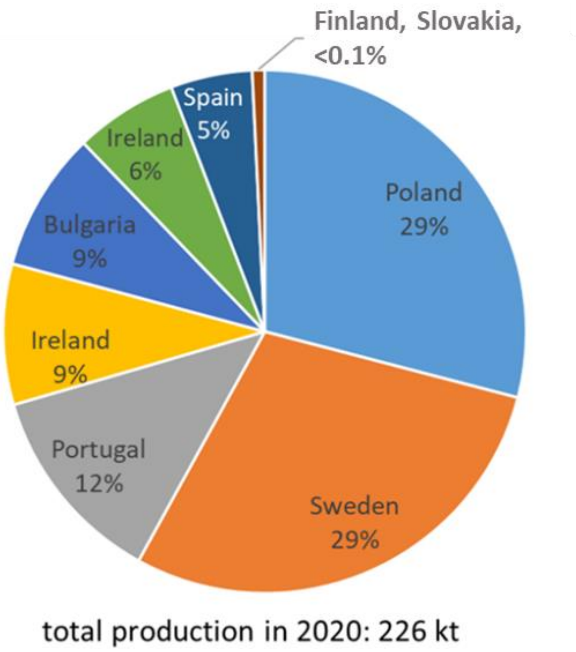

Figure 13. EU lead mine producers in 2020 (BGS, 2022).

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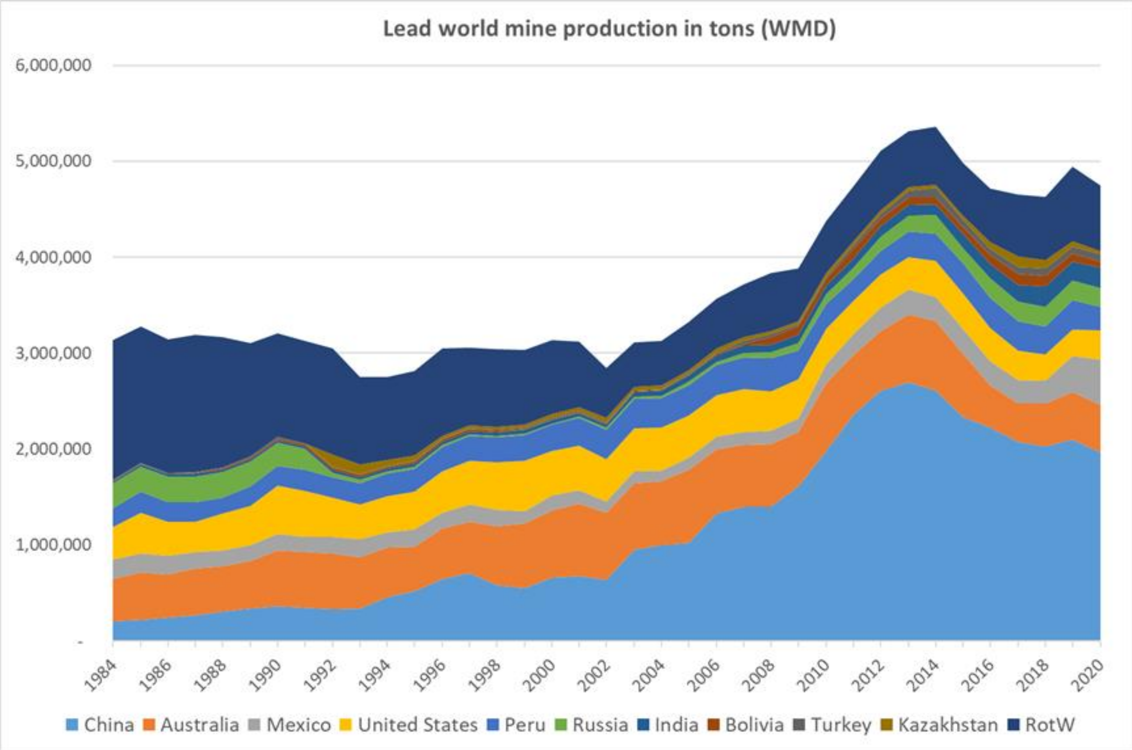

Figure 14. Global lead production from 1984 to 2020 (WMD, since 1984).

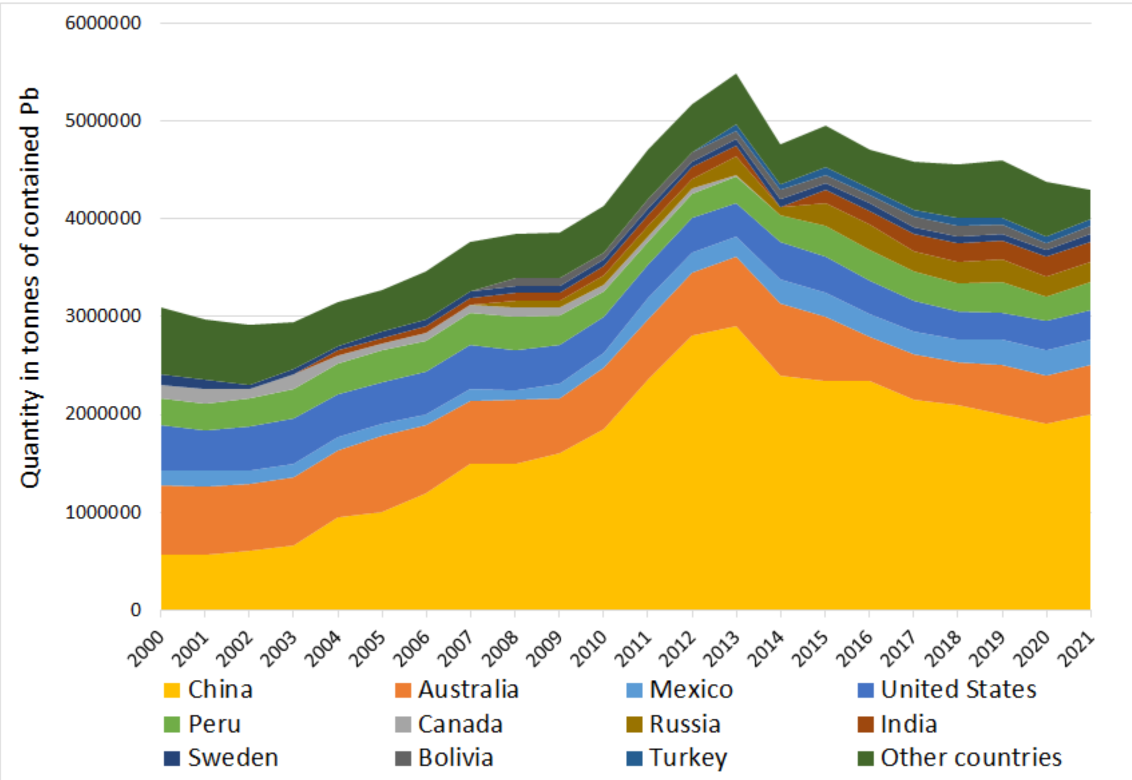

Figure 15. Global lead production from 2000 to 2021 (USGS, since 2000).

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OUTLOOK FOR SUPPLY

Lead ore and concentrates production in Europe has shrunk by 44% to around 0.45 million tonnes since 1988, while in Asia, production has experienced fast growth and reached 2.65 million tonnes in 2018 (ILZGS 2018). Similarly, production of refined lead has increased significantly only in Asia, while output in Europe, the Americas, and Oceania remained stable.

In the Asia-Pacific region, Dairi (Sumatra), Lakuwahi (Indonesia), and Naimanqi Zinc Lead Mine project (China) are the key mining development projects (GlobalData, 2022). In Europe, projects are the Yenipazar (Turkey), Rupice (Bosnia and Herzegovina), and Olza (Poland), in the Eurasian countries, amongst the most promising projects are the Gorevskoe, Kholodninskoe and Ozernoe Mine projects in Russia (GlobalData, 2022).

On a global scale, secondary lead production by recycling has increased steadily from 55% to 63% of the total refined lead production from 2013 to 2018 (ILZGS 2018). However, output are regionally very different: in the Americas secondary refined lead production accounted for 89% of the total refined metal production, in Europe 79%, and in Asia only 51%, showing a huge potential for growth in secondary refined lead output in Asia (ILZGS 2018).

SUPPLY FROM SECONDARY MATERIALS/RECYCLING

POST-CONSUMER RECYCLING (OLD SCRAP)

Lead has one of the highest recycling rates of all materials in common use to-date. More refined lead is produced by recycling than from mines. World annual secondary lead production amounted to 6,300 kt on average over the period 2012-2016, representing 57% of the total metal output (ILZSG, 2017).

Lead was recycled in 20 EU countries EU: Austria, Belgium, Bulgaria, Croatia, Czech Republic, Estonia, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain and Sweden. The EU secondary refined lead production increased by 3% over the period 2012-2016 with an average output of about 1,146 ktper year, which was 80% of the EU total refined lead production. Germany was the largest producer with about 22% of the total production of the EU, followed by Spain, Italy and Belgium. Most of this production results from the processing of waste generated in the EU and from a small amount of imported scraps.

Most of the secondary lead comes from scrap lead-acid batteries, lead pipe, sheet and cable sheathing. Scrap lead from the building trade is usually fairly clean and is re-melted without the need for smelting, though some refining operations may be necessary (International Lead Association, 2016). Lead batteries are the only battery system that is almost completely recycled. In the EU, recycling efficiencies of lead-acid batteries for a vast majority of countries were above 75% in 2017 (Eurostat, 2019c); 99% of the automotive lead-based batteries which were collected have been recycled during the period 2010-2012 (IHS, 2014). More than 95% of the lead sheet used in the construction industry for roofing was collected and recycled (The European Lead Sheet Industry Association, 2016). Pipe scraps, sludge, dross and dusts were also recycled.

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PROCESSING OF LEAD

The conventional process for smelting lead starts by removing the sulphur from the concentrates which is normally achieved by a roasting and sintering process which turns the lead sulphides into lead oxide and converts most sulphurs into sulphur dioxide (SO2). The lead oxide (the sintered concentrate) is then fed to a blast furnace together with limestone and coke in order to reduce the oxide to metal. Alternatively, direct smelting systems perform roasting, sintering and smelting in a single furnace (e.g. Isasmelt furnace). The crude lead coming from the smelting furnace may still contain impurities (e.g., copper, Arsenic, antimony, tin, bismuth, zinc, silver, gold) and needs to be refined.

Stages of purification (and recovery of precious metals) include "drossing and decopperization" by sulphur addition and the Harris process (addition of molten caustic soda and salt), followed by a pyrometallurgical process (desilverization via zink addition: Parkes process) or an electrometallurgical process (anode casting plus Fluosilicic acid treatment) (Figure 16).

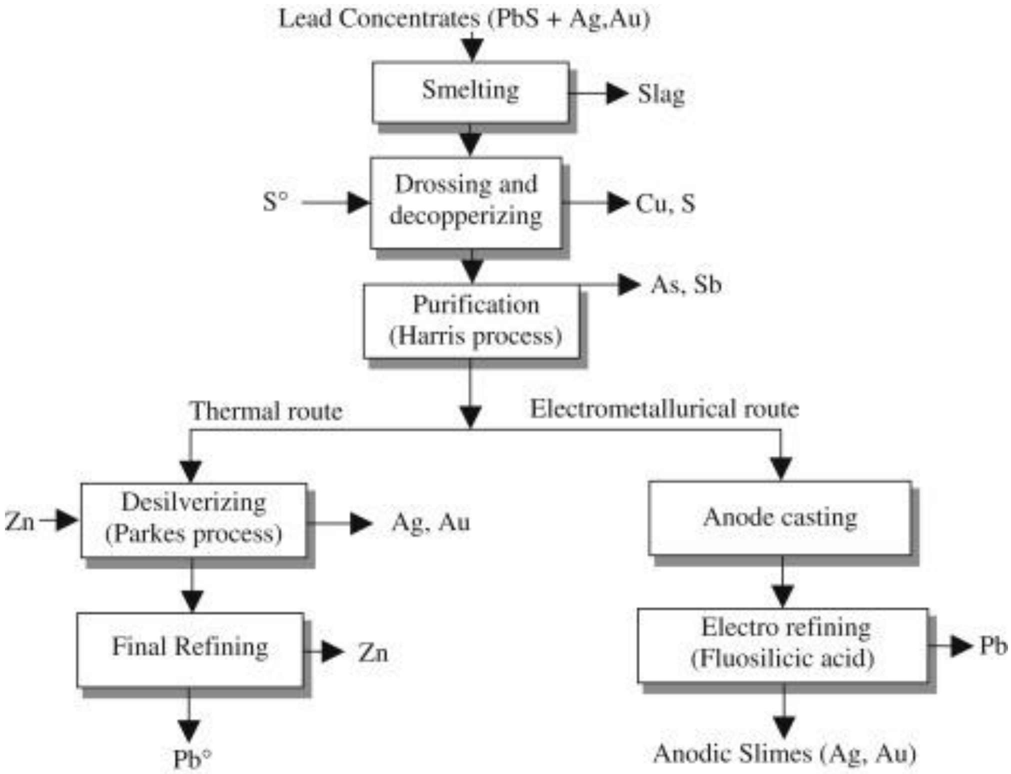

Figure 16. Simplified processes for lead purification and recovery of e.g., gold and silver from galena (PbS) concentrate after smelting (Ferron 2016).

World refined lead metal production amounted to ~12,000 kt per year on average during the period 2016-2020 (BGS, 2022). China is the world leading supplier with ~43% (5,174 kt per year) of the global production, followed by the United States contributing 1,142 kt per year, and South Korea 628 kt per year (BGS, 2022). Overall, refined lead production is a highly concentrated industry with those producing countries with an output above 100,000 tonnes in 2018 contributing 88% of world production (ILZSG 2019).

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OTHER CONSIDERATIONS

HEALTH AND SAFETY ISSUES

Lead is primarily associated with toxicity hazards. Exposure to lead through ingestion or inhalation may result in different types of physiological damages: neurological (e.g. neurological deficits), haematological (e.g. risk of anaemia), endocrine (e.g. potential disruption in cell growth and maturation), renal (kidney diseases), reproductive (damages to fertility or to the unborn child), and carcinogenic (ILO, 2011). Moreover, lead is also very toxic to aquatic life (ECHA, 2023).

Lead and lead compounds are included in REACh Annex XVII. The placing on the market and use in certain products/applications of these substances is therefore restricted. In addition, elemental lead as well as several lead compounds are also included in the list of substances of very high concern (SVHCs). The lead compounds were additionally adopted to Annex XIV, which lists substances that cannot be placed on the market or used unless such uses have been authorised by the European Commission upon request (ECHA, 2023).

The main route of exposure to lead in an industrial context is through inhalation of dust/powder particles generated in the working atmosphere (e.g. vapours/fumes occurring during lead metal heating) (IFA, 2023). To prevent potential risks of exposure to lead, the ILO recommends to avoid the formation of dust as far as possible, e.g. by use of water sprays to prevent the formation of airborne dust. This should come along with adapted personal protective equipment, to protect workers from any exposure to lead (ILO, 2011).

ENVIRONMENTAL ISSUES

Lead is generally exploited from sulfidic deposits, which implies a potential risk of acid mine drainage[5] from the generated wastes (German Environmental Agency, 2020).

In an LCA study carried out by the International Lead Association (ILA), the environmental impacts of refined lead production are calculated to amount to 1.31 kg CO_2-eq/kg refined lead considering the global warming potential (GWP) impact category. Smelting as well as mining and concentration operations were identified as the main sources of GWP impacts, in particular due to direct on-site emissions resulting from the process and indirect emissions induced by power generation. In terms of primary energy demand, the production of refined lead induces a total consumption of 18.5 MJ/kg refined lead (Davidson et al., 2016).

On a per kilogram basis, lead is one of the metals with the lowest environmental impacts (among 63 metals) considering five impact categories: GWP, cumulative energy demand, terrestrial acidification, freshwater eutrophication, human toxicity. However, it is noteworthy that when considering its global annual production volume (which is significantly high compared to other metals), lead stands among the most impactful metals in particular in terms of global warming potential (Nuss and Eckelman, 2014).

[5] Formation and runoff of acidic water that is rich in heavy metals

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NORMATIVE REQUIREMENTS

Directive 2011/65/EU (RoHS Directive) restricts the use of cadmium in electrical and electronic equipment (EEE) to a maximum concentration of 0.1 % in each individual homogeneous material of the EEE (RoHS 2011). Equivalently, Directive 2000/65/EC (ELV Directive) restricts the use of cadmium in most vehicles.

Since lead-acid batteries from vehicles and photovoltaic energy generation and storage are a major source of severe environmental and health hazards in low- and middle-income countries, the Basel Convention Secretariat published "Technical Guidelines for the Environmentally Sound Management of Waste Lead-acid Batteries". (BC 2003) The US-EPA provides information on Lead Policy and Guidance related to lead in air, soil, and water, and in certain products. (EPA 2023)

In the US, Congress has passed several laws related to lead. These laws address lead in paint, dust and soil; lead in the air; lead in water; and disposal of lead waste. EPA is addressing lead contamination and resulting hazards under these laws in many ways, including by issuing and enforcing regulations. EPA also helps the regulated community understand the federal requirements with policy and guidance documents to assist in complying with the regulations (EPA 2023).

While there are no specific indications for storing or transporting/shipping lead, lead ore shall be kept as dry as practicable before loading, during loading and during the voyage. (Cargo Handbook 2023)

RESEARCH AND DEVELOPMENT TRENDS

RESEARCH AND DEVELOPMENT TRENDS FOR LOW-CARBON AND GREEN TECHNOLOGIES

- Lead-halide perovskites as new materials for next generation of photovoltaic cells

During the last decade, lead-halide perovskites emerged as promising new material for the next generation of photovoltaic cells and, more in general, optoelectronic, owing to their superior optical absorption coefficients, long carrier diffusion lengths, high defect tolerance, ect. [Jena et al. 2019]. Today, the certified Power Conversion Efficiency (PCE) of laboratory-scale devices based on perovskites solar cells has exceeded 25% [U.S. National Renewable Energy Laboratory, 2022]. However, the most efficient cells are prepared from perovskites made of lead salts, as PbI_2 and $PbBr_2$, soluble in water and thus potentially toxic [Schileo et al. 2021]. In addition to lead toxicity, the major obstacle in the way of commercialization is the lack of stability of these devices under real operational conditions, especially for longer duration use [Mazumdar et al. 2021].

- HY-NANO[6]: HYbrid NANOstructured multifunctional interfaces for stable, efficient, and eco-friendly photovoltaic devices (2019-2024, ERC EU)

Nowadays, low-cost three-dimensional (3D) Hybrid Perovskites solar cells are revolutionizing the photovoltaic scene, with stunning power conversion efficiency beyond 22%. However, poor device stability (due to degradation in contact with water) and dependence on toxic components (lead) substantially hamper their

[6] https://cordis.europa.eu/project/id/802862

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commercialization.

HY-NANO aims to realize a new low-cost and efficient hybrid solar technology based on Hybrid Perovskites cells combining long-term stability with a reduced environmental impact. Design and engineering innovative multi-dimensional hybrid interfaces is the core idea of the project. In addition, the project aims to the development of new solar cell encapsulant using metal-organic frameworks (MOFs) functionalized as selective lead receptors to minimize the environmental risks associated with the potential release of lead.

OTHER RESEARCH AND DEVELOPMENT TRENDS

- BeLEADFREE[7] project:- High Strength Bearing for Large-Bore LEAD FREE Engines (2016 – 2018, EU)

Lead (Pb) is a heavy metal very harmful to health and the environment. The large-bore engine industry still heavily relies on lead-based journal bearings. Seven tonnes of lead will be released to the environment from large-bore engines manufactured in 2015.

BeLEADFREE aimed to deliver novel lead-free journal bearings to large-bore engine builders worldwide, ranging from medium and heavy-duty diesel engines (e.g. commercial road vehicles) to large four-stroke medium-speed engines (e.g. ships, engine generators or gensets). This will be achieved by optimising novel manufacturing approaches that have proven successful at TRL6 and designing and building a pilot line to manufacture lead-free journal bearings to be validated in real engine working conditions.

- Prenatal and postnatal lead exposures and intellectual development among 12-year-old Japanese children (Tatsuta et al 2020)

Low-level lead exposure during childhood is associated with deficit in child IQ. However, the association between prenatal lead exposure and child IQ remains inconsistent. The objective of our study was to examine the association between prenatal/postnatal lead exposure and child IQ at the age of 12. The data were obtained pertaining to cord-blood and child-blood lead levels and IQ for 286 children from a prospective birth cohort study (Tohoku Study of Child Development). IQ was assessed using the Wechsler Intelligence Scale for Children-Fourth Edition. Simultaneously, the Boston Naming Test (BNT) was used to assess the children's language ability. Postnatal lead exposure adversely affects the intellectual ability in boys. Furthermore, the language ability is sensitive to prenatal/postnatal lead exposure in boys.

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