Horizon 2020 Programme

SCRREEN2

This project has received funding from the European

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

Solutions for CRitical Raw materials - a European Expert Network

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

BERYLLIUM

AUTHOR(S):

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BERYLLIUM

OVERVIEW

The beryllium (Be) is a lightweight, dark, silver-grey metal with high thermal stability and conductivity, flexural rigidity. Be is a relatively rare element with a concentration of about 2.8-3 ppm in the earth's crust, and 2.1 ppm in the uppercrust (Rudnick, 2003). Until the late 1960s the only beryllium mineral commercially exploited was beryl (Be3Al2Si6O18). Today the most important commercial beryllium mineral is bertrandite (over 75% of mining operations) which is extracted from ores containing 0.3-1.5% beryllium. Beryllium market is expected to grow considerably owing to good demand from the computer and teleco mmunications infrastructure markets and the increasing automotive electronics market (MCGroup, 2022). Furthermore, demand from emerging markets in Asia and Latin America is expected to increase in upcoming years.

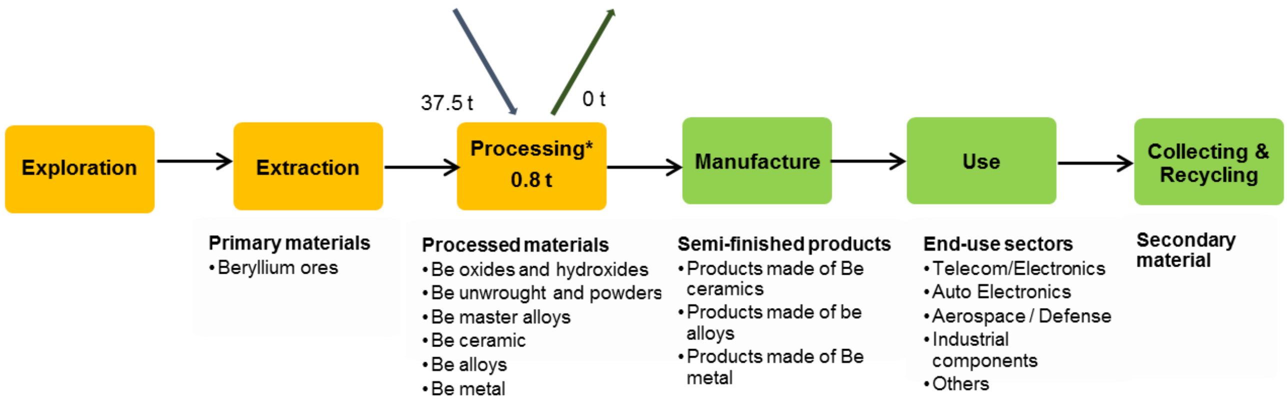

Figure 1. Simplified value chain for beryllium in the EU[1]

Table 1. Beryllium supply and demand in metric tonnes (processing stage, BeST data), 2016-2020 average

Global production	Global Producers	EU consumption	EU Share	EU Suppliers	Import reliance
234	USA 50% Kazakhstan 25% Japan 17% China 8%	34.5	15%	USA 60% Kazakhstan 25% Japan 10% China 5%	100%

Prices: The price of beryllium depends on the form in which it is traded (BeST, 2022). The beryllium prices during 2020-2021 were driven by the demand in aerospace and defence, automotive, and industrial components (USGS, 2022). Beryllium price volatility in 2016-2021 was around 13%, thus, there were no major changes in prices in the past 5 years.

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

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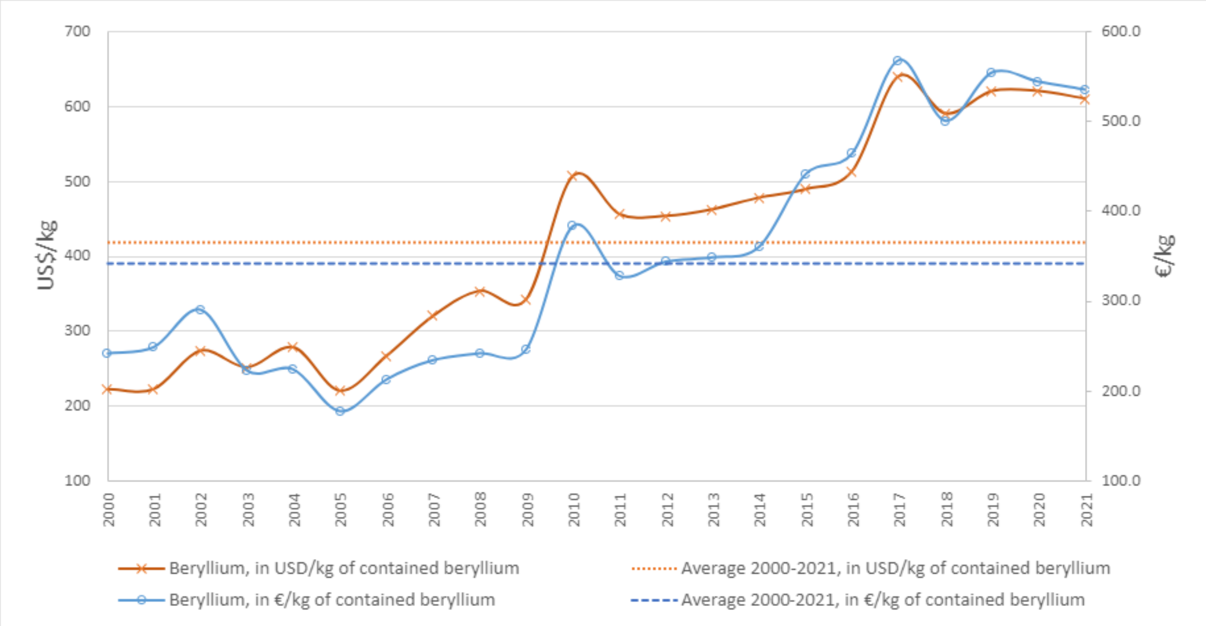

Figure 2. Annual average price of beryllium 2000 and 2021, in US$/kg and €/kg [1] (USGS, 2022).

Primary supply: USA and China are only major producers since 2002. Beryllium concentrate production in USA and China represented 70% and 25%, respectively of the total global production in 2020 (WMD, since 1984). The annual average production over 2016-2020 was about 234 tonnes/year.

Secondary supply: There is no known post-consumer functional recycling of beryllium in Europe and in the world. Beryllium is not recycled from end finished products (BeST, 2016b), therefore the end of life recycling input rate is 0%. The recuperation of pure metal of beryllium from end finished products is extremely difficult because of the small size of components and the tiny fraction of beryllium contained in appliances (less than 40 ppm in appliance having the highest amount of Be) (BeST, 2016b).

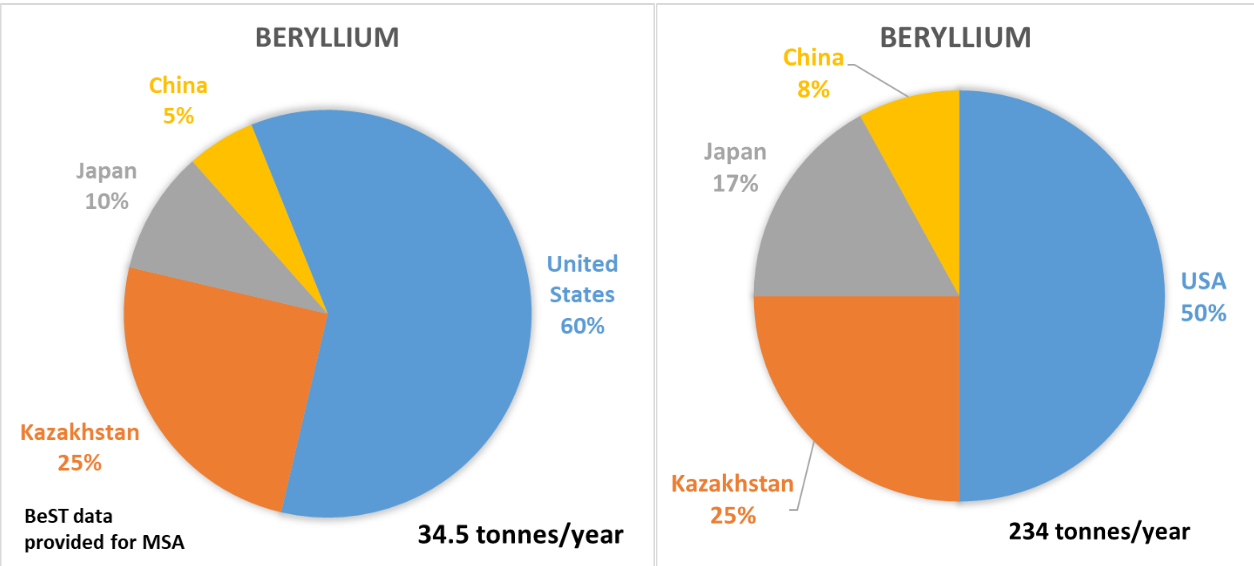

Figure 3. EU sourcing and global production (processing) of beryllium (average 2016-2020)

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Uses: In the EU, the consumption of processed beryllium materials is about 34.5 tonnes per year of beryllium content over the average 2012-2016 (BeST, 2019a). For 2019-2020, the apparent annual EU consumption of beryllium at processing stage is in the range between 37.5 tonnes and 24.8 tonnes. Approximately 80% of beryllium used in the EU goes into copper-beryllium alloys (containing 0.2-2% of beryllium) for the manufacture of high performance electrically conductive terminals and mechanical components. About 15% of beryllium is used in the form of pure metal or in a metal matrix containing over 50% beryllium. Copper-beryllium is used when reliability is essential to ensure safe operation in the defence, transport or energy sector. Pure beryllium and aluminium-beryllium (with 62% of beryllium) are used only in applications where the unique property combinations are essential for mission capabilities. (BeST, 2016a).

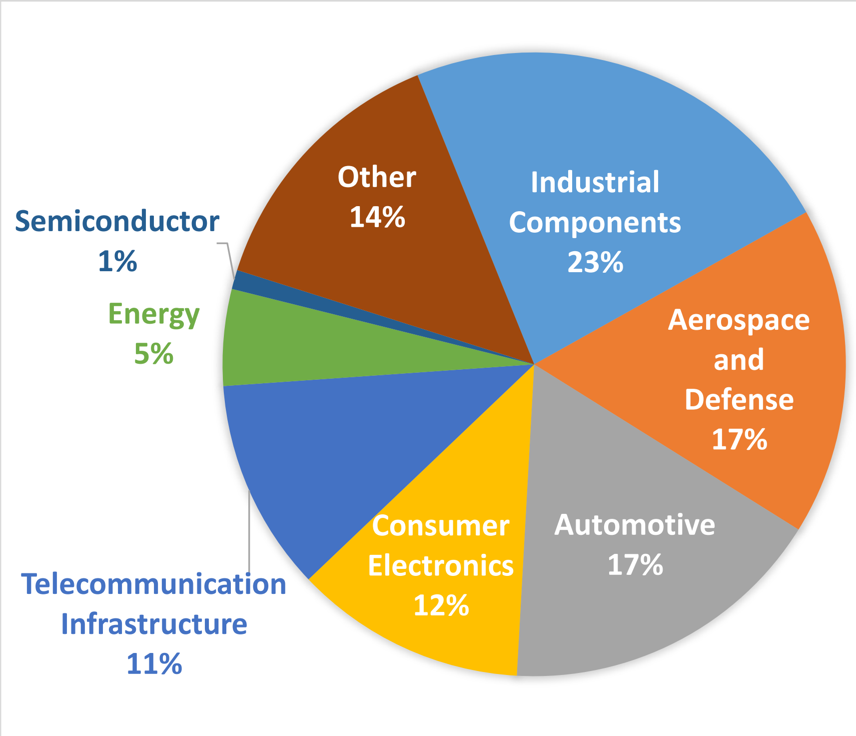

Figure 4: EU uses of beryllium (BeST 2023)

Substitution: Substitution of beryllium always leads to a loss of performance. As beryllium is expensive, it is used only when it is absolutely needed (Freeman, 2016).

Other issues: The use/ban of Beryllium is restricted under REACH Regulation (EC) No 1907/2006 Annex XVII (Deutsche Forschungsgemeinschaft and Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area, 2002). The REACH Regulation (EC) No 1907/2006 Annex XVII, Point 28 states that the substance shall not be placed on the market or used as a substance or as a constituent of other substances or in mixtures for supply to the general public when the concentration of the substance or mixture reaches or exceeds the concentration limits according to the CLP Regulation. The International Agency for Research on Cancer (IARC) and the EU Carcinogens and Mutagens Directive (Directive 2004/37/EC) and the EU's Regulation on Classification, Labelling and Packaging of substances and mixtures (Regulation (EC) No 1272/2008) recognizes beryllium and beryllium compounds as a Group 1 carcinogen (Niu et al. 2022; 'EU Regulations' 2016).

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Table 2. Uses and possible substitutes

Use	Percentage*	Substitute	Comment on substitute**
Electronic and telecommunications equipment	42%	Possible substitutes include: • Copper nickel tin alloy • Titanium-copper alloy • Copper nickel silicon alloy • Copper lead tin alloy • Aluminium / Lead / Manganese • Copper Iron Phosphorous alloy • Copper Tin Phosphorous alloy • Silicon • Boron nitride	Reduced performances Similar costs
Transport and Defence: Vehicle electronics	17%	Possible substitutes include: • Copper zinc alloy • Copper tin alloy • Copper nickel tin alloy • Copper lead tin alloy • Aluminium / lead / manganese • Copper iron phosphorous alloy • Copper nickel silicon alloy	Reduced performances Similar costs
Transport and Defence: Automobile components	17%	Possible substitutes include: • Aluminium alloys • Magnesium alloys • Aluminium metal matrix composites • Titanium alloys • Carbon reinforced composites	Similar costs, similar performance
Transport and Defence: Aerospace components	10%	Possible substitutes include: • Copper nickel tin alloy • Aluminium alloys • Aluminium metal matrix composites • Titanium alloys • Magnesium alloys • Carbon reinforced composites	

***EU end use share of Beryllium (SCRREEN, 2019 & 2021; SCRREEN EC Draft Data 2025-30; BeST, 2019)**
**** SCRREEN draft EC Data 2023-25**

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MARKET ANALYSIS, TRADE AND PRICES

GLOBAL MARKET

The global beryllium production at the processing stage was 234 tonnes/year in average on 2016-2020. The producers were USA (50%), Kazakhstan (25%), Japan (17%) and China (8%). Data from EUROSTAT are very different from those of BeST. BeST were used for the evaluation.

Table 3. Beryllium supply and demand (processing) in metric tonnes, 2016-2020 average

Global production	Global Producers (USGS)	EU consumption	EU Share	EU Suppliers (BeST)	Import reliance
234	USA 50% Kazakhstan 25% Japan 17% China 8%	34 5	15%	USA 60% Kazakhstan 25% Japan 10% China 5%	100%

Beryllium annual consumption is expected to grow more than 450 tonnes per year by 2030, driven by applications such as the construction of the ITER fusion reactor (BeST, 2022). In 2021, the largest consumers of beryllium compounds were the US and the EU. In Asia-Pacific (primarily in China), the beryllium demand has increased to the volumes closer to the European level (MCGroup, 2022).

Beryllium market is expected to grow considerably owing to strong demand from the computer and telecommunications infrastructure markets and the increasing automotive electronics market (MCGroup, 2022). Furthermore, demand from emerging markets in Asia and Latin America is expected to increase in upcoming years.

EU TRADE

Table 4. Relevant Eurostat CN trade codes for beryllium

Processing/refining	
CN trade code	**title**
2825 90 20	Beryllium oxide and hydroxide
8112 12 00	Beryllium: Unwrought; powders

For information, EUROSTAT data are reported below with the CN codes given above. However, these data are quite different from the ones available through BeST, with an average annual import of 34.5 tonnes coming from USA (60%), Kazakhstan (25%), Japan (10%) and China (5%). Only BeST data were considered in the criticality assessment.

Figure 5 and Figure 6 show the EU trade in beryllium compounds, in tonnes of unwrought beryllium, and beryllium oxides and hydroxides, between 2000 and 2021. The EU was a net importer of beryllium compounds. The EU imports of oxides and hydroxides (CN 28259020) are only reported for the year 2003, while beryllium oxides and hydroxides exports have been reported more regularly. However, this make such data difficult to

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exploit. The EU imports of beryllium, unwrought (CN 81121200) are low since 2012 (lower than 10 tonnes), the EU exports have been close to 0 tonnes for the last 20 years.

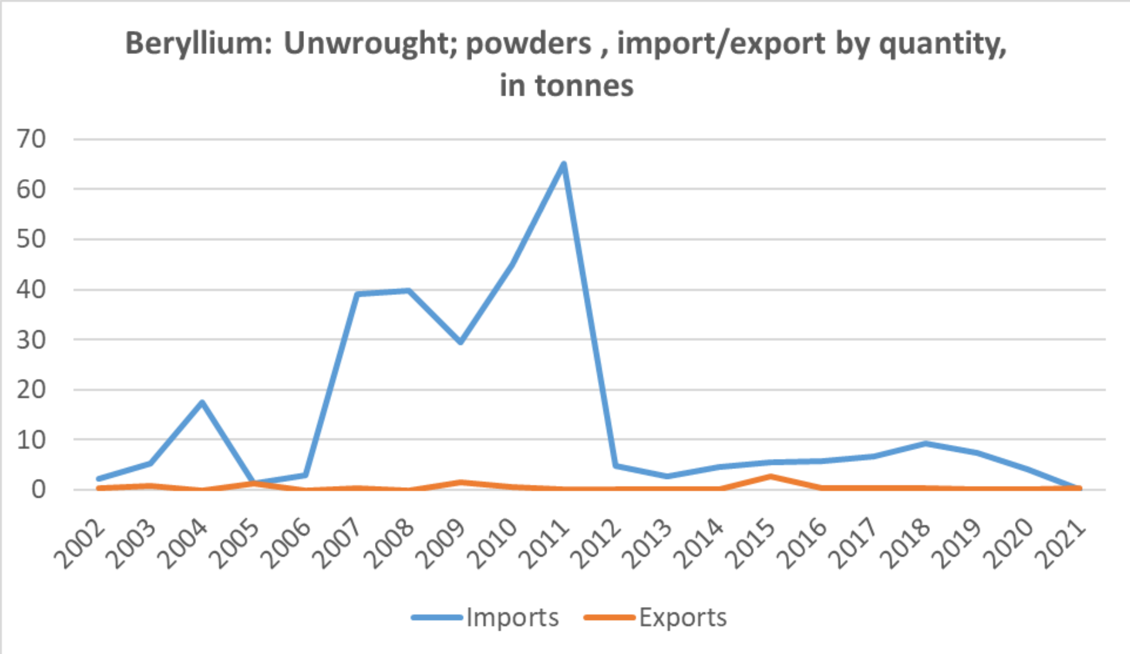

Figure 5. EU trade flows of beryllium, unwrought (CN 81121200) from 2002 and 2021 (Eurostat, 2022)

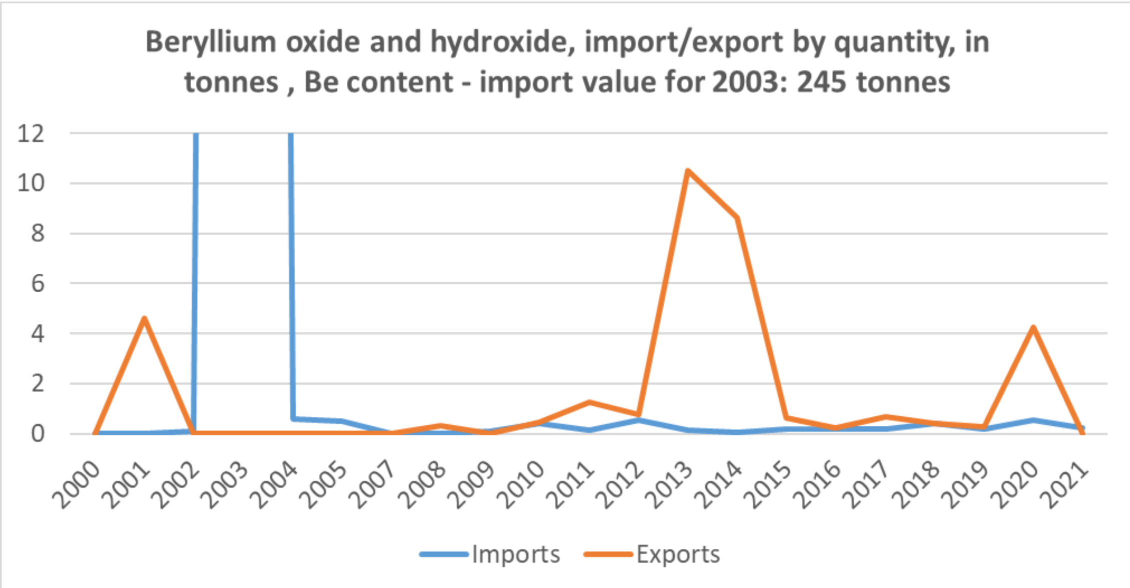

Figure 6. EU trade flows of beryllium oxides and hydroxide (CN 28259020) from 2000 and 2021 (Eurostat, 2022)

Figure 7 and Figure 8 present the average EU imports of beryllium compounds by country for the period 2000-2021. The major EU supplier of beryllium oxide and hydroxide in 2003 was the UK, which corresponds to 98% of the EU's beryllium oxide and hydroxide imports that year, the only one with reported data. For beryllium,

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unwrought, the main supplier was also the UK, which represents more than 95% of total EU's imports since 2007.

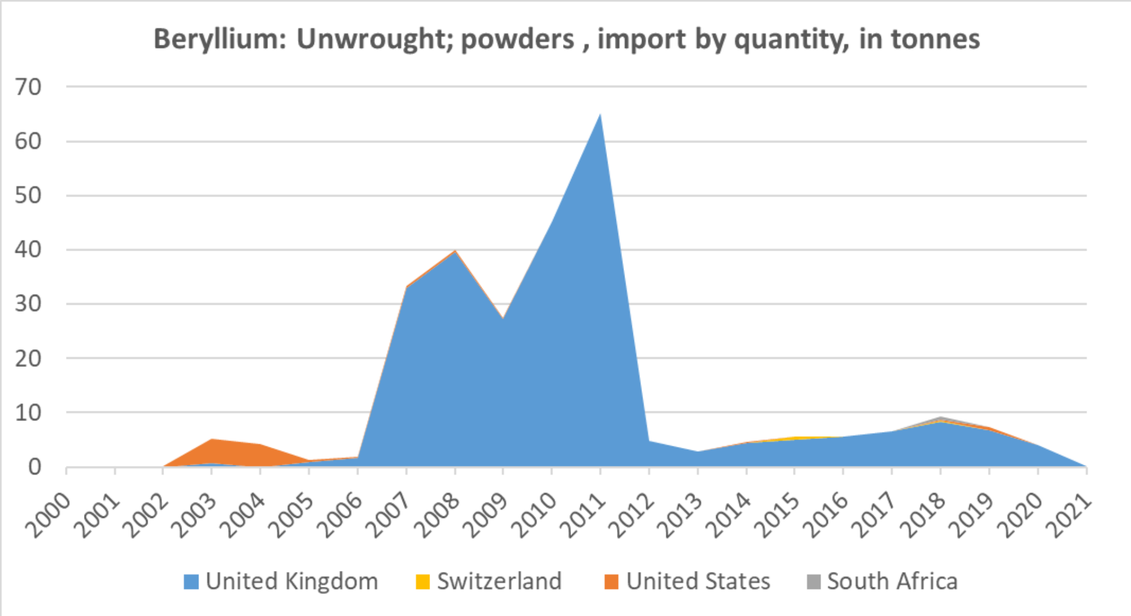

Figure 7. EU imports of beryllium, unwrought (CN 81121200) by country between 2002 and 2021 (Eurostat, 2022)

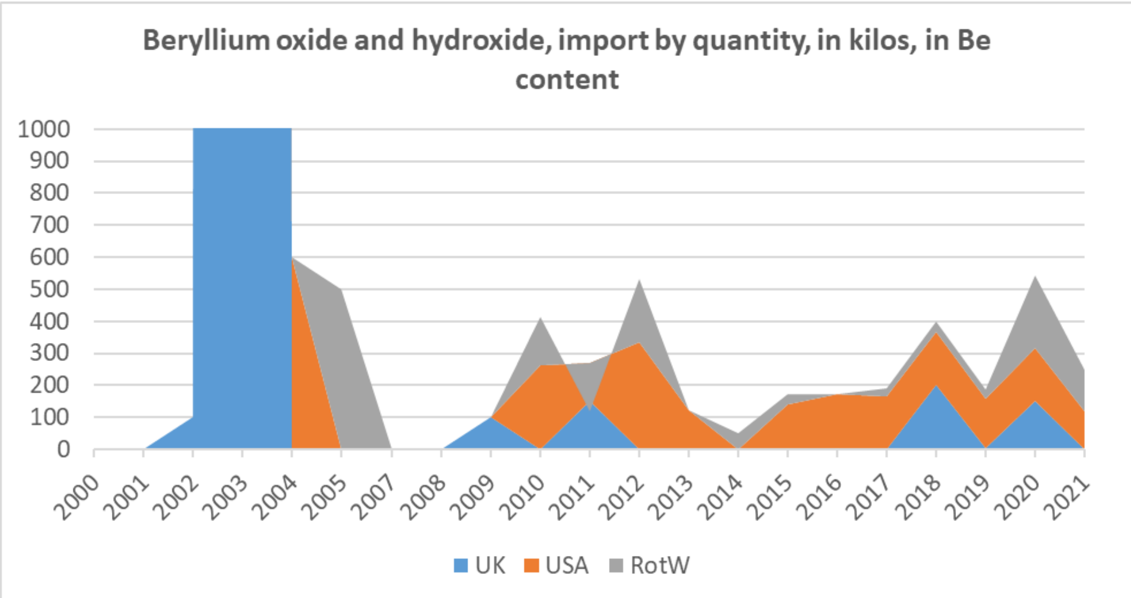

Figure 8. EU imports of beryllium oxides and hydroxide (CN 28259020) by country between 2000 and 2021 (Eurostat, 2022) – the reported value for year 2003 was 245000 kg (245 tonnes)

AS mentioned above, an additional set of data was collected from the BeST association for the 2016-2020 period of time at the occasion of the MSA exercise 2023 (Figure 9).

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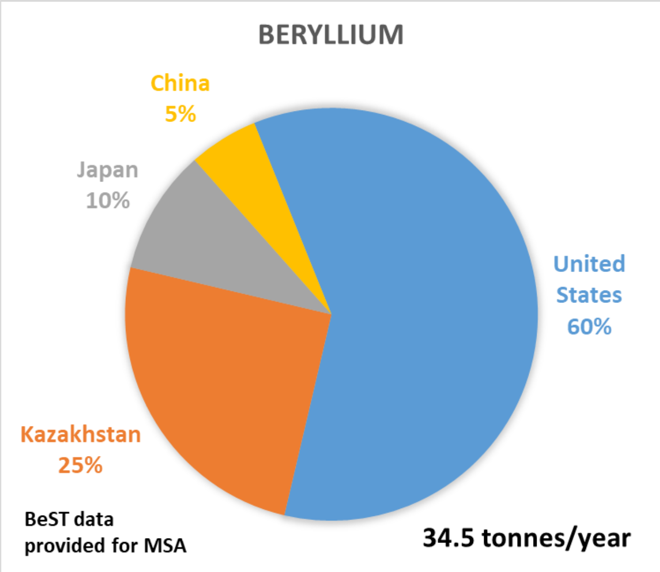

Figure 9. EU imports of beryllium (no code) by country, average 2016-2020 (BeST 2023, data collected for MSA study 2023)

PRICE AND PRICE VOLATILITY

The price of beryllium depends on the form in which is traded (BeST, 2022). The beryllium prices during 2020-2021 were driven by the demand in aerospace and defence, automotive, and industrial components (USGS, 2022). Beryllium price volatility in 2016-2021 was around 13%, thus, there were no major changes in prices in the past 5 years.

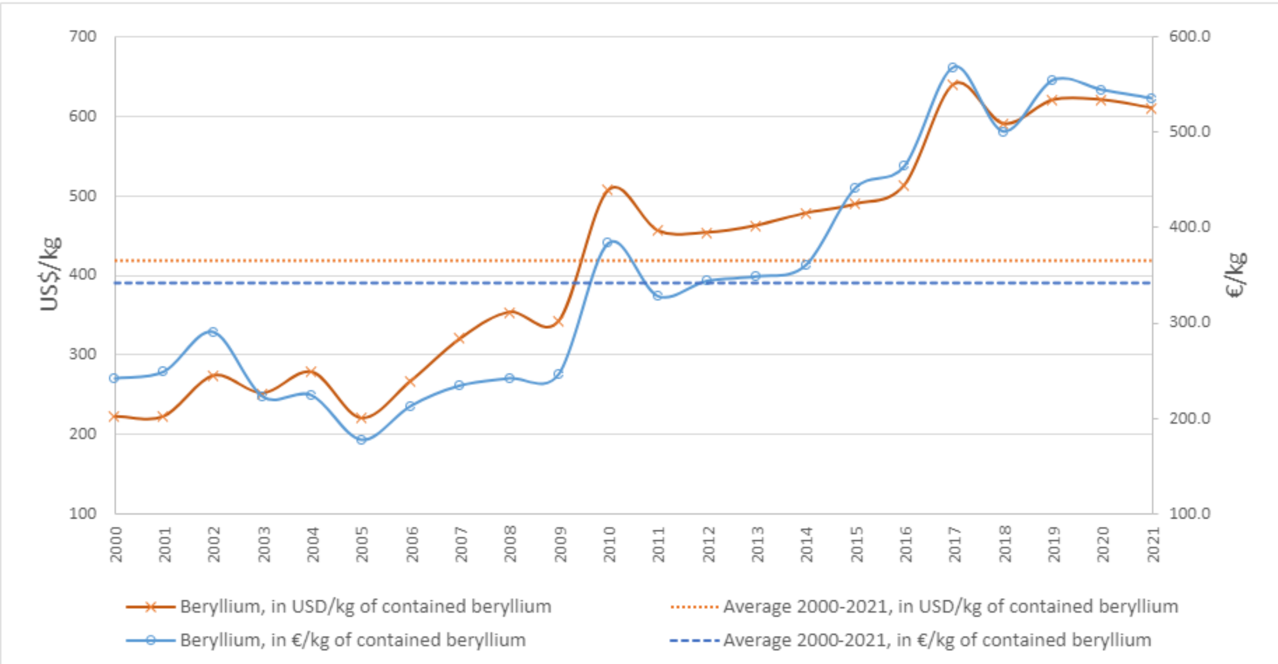

Figure 10. Annual average price of beryllium 2000 and 2021, in US$/kg and €/kg (USGS, 2022)

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DEMAND

GLOBAL AND EU DEMAND AND CONSUMPTION

Beryllium extraction stage is presented by HS code 2617900003 Beryllium ores and concentrates. However, there is no reported EU production, import and export using this trade code.

Beryllium processing stage EU consumption is presented by HS codes CN 28259020 Beryllium oxide and hydroxide, and CN 81121200 and CN 81121110 Unwrought beryllium; beryllium powders. Import and export data is extracted from Eurostat Comext (2022).

In the EU, the consumption of processed beryllium materials is about 34.5 tonnes per year of beryllium content over the average 2012-2016 (BeST, 2019a). However, based on EUROSTAT, the total imports of beryllium metal and beryllium oxide, are only about 7 tonnes/year, in Be content. According to PRODCOM (2022), for 2019-2020, the apparent annual EU production of beryllium at processing stage is 430 tonnes. This figure seems totally biased according to the international market (234 tonnes/year). In agreement with the EU Commission, it has been decided to disregard this production (PRCCODE 24453060 for unwrought beryllium; beryllium powders and PRCCODE 20121960 for Beryllium oxide and hydroxide). The EU consumption is therefore estimated at 35 tonnes/year (imports-exports) on 2016-2020 period of time based on BeST data. Therefore, Figure 11 based on EUROSTAT data is given for information only and is not to be considered.

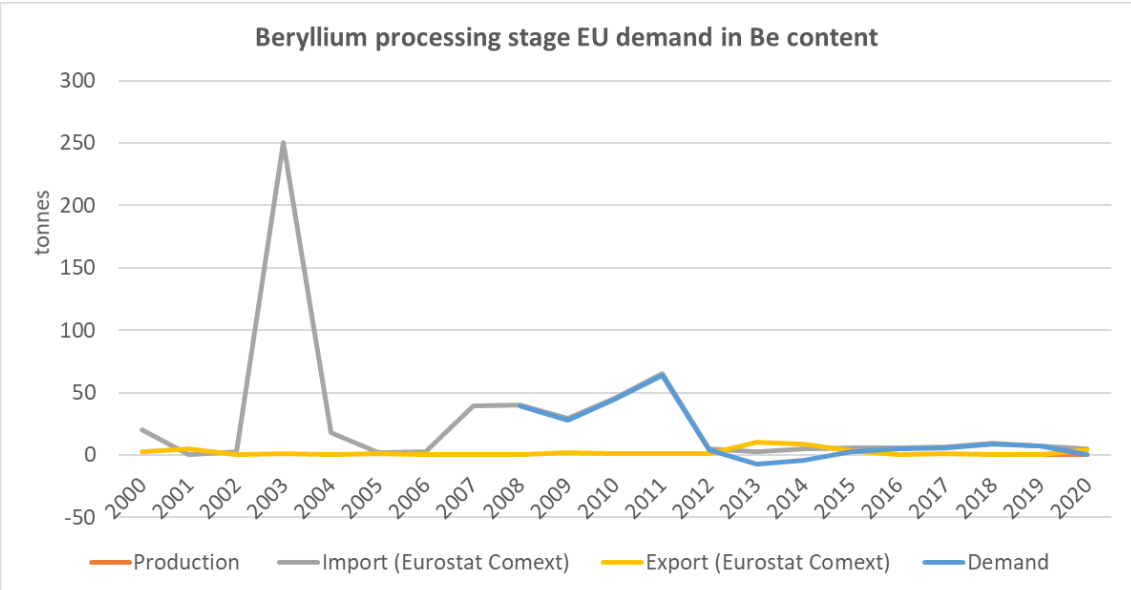

Figure 11. Beryllium (CN 28259020 and CN 81121200 and CN 81121110) processing stage apparent EU consumption.

Approximately 80% of beryllium used in the EU goes into copper-beryllium alloys (containing 0.2-2% of beryllium) for the manufacture of high performance electrically conductive terminals and mechanical components About 15% of beryllium is used in the form of pure metal or in a metal matrix containing over 50% beryllium. Copper-beryllium is used when reliability is essential to ensure safe operation in the defence,

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transport or energy sector. Pure beryllium and aluminium-beryllium (with 62% of beryllium) are used only in applications where the unique property combinations are essential for mission capabilities. (BeST, 2016a).

Beryllium's superior chemical, mechanical and thermal properties make it a favourable material for high technology equipment (e.g., in aerospace) for which low weight and high rigidity are important qualities. A large share of global pure beryllium production is used for military purposes. Due to the high price and unique properties, only small amounts of pure beryllium are used in the civilian sector (European Commission, 2014; Freeman, 2016).

Based on BeST data, average import reliance of beryllium at processing stage is 100% for 2016-2020.

EU USES AND END-USES

Figure 12 presents the main uses of beryllium in the EU over the year 2012-2016. Data remains unchanged from that presented in 2020 factsheets.

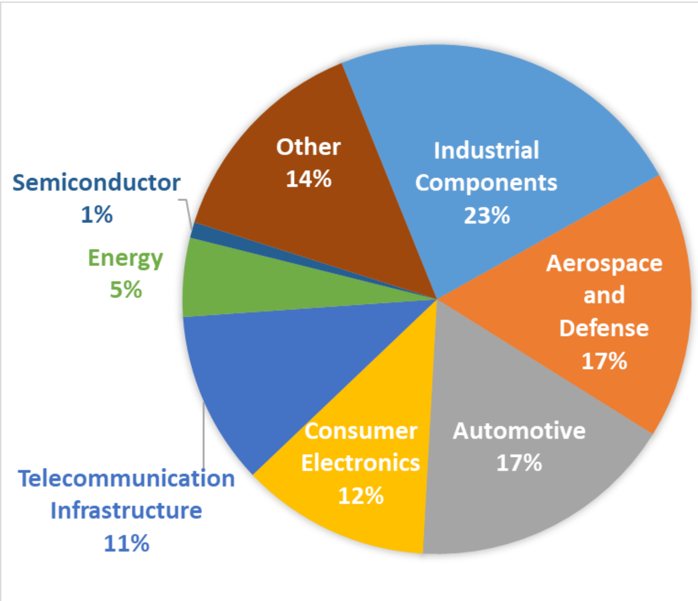

Figure 12: EU end uses of Beryllium. (SCRREEN experts, 2019 & 2021; BeST, 2019)

The end-uses of beryllium products in the EU are summarised below (SCRREEN CRM Experts, 2019 & 2021):

ELECTRONICS AND TELECOMMUNICATION EQUIPMENT

Beryllium is used as an alloying element in copper to improve its mechanical properties without impairing the electric conductivity.

Copper beryllium is used in electronic and electrical connectors, battery, undersea fibre optic cables, chips (consumer electronics + telecommunications infrastructure)

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TRANSPORT & DEFENCE

Automotive electronics: connectors in vehicle components (Copper-Beryllium - CuBe) for air-bag crash sensor and deployment systems, airbags, anti-lock brake systems and many other life safety applications, for weather forecasting satellites, undersea earthquake tsunami detection monitors, air traffic control radar, fire sprinkler systems (Nickel-Beryllium (NiBe), power steering and electronic control systems, etc.

Other light metal vehicle components (Be used for recycling process of magnesium containing light alloys in <10 ppm): car body panels, seat frames, car steering components and wheels, etc.

AEROSPACE

Used in components within landing gears, aircraft engines, mirrors for satellites, etc.

INDUSTRIAL COMPONENTS

Beryllium is as moulds for rubber and plastics, made of CuBe alloys, and in metals (bars, plates, rods, tubes, and customised forms).

ENERGY APPLICATIONS

Copper-beryllium is used to deal with leaks from oil spills, in non-magnetic equipment, in down-hole equipment and in non-sparking safety equipment used to improve extraction equivalent of energy applications.

Pure beryllium is used in fusion research and fission energy production.

OTHERS

Beryllium is used in medical applications. Beryllium foil for high-resolution medical radiography, including CT scanning and mammography; beryllium oxide ceramic in lasers; beryllium as components to analyse blood and in X-ray equipment, etc.

Relevant industry sectors are described using the NACE sector codes (Eurostat, 2022) as set out below:

Table 5. Beryllium applications, 2-digit and associated 4-digit NACE sectors and value added per sector (Data from the Eurostat database; Eurostat, 2022c)

Applications	2-digit NACE sector	Value added of 2-digit NACE sector (M€) – as at 2019	4-digit NACE sectors
Electronic and telecommunications equipment	C26 - Manufacture of computer, electronic and optical products	84,074*	C2610 Manufacture of electronic components, C2630 Manufacture of communication equipment

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Transport and Defence: Vehicle electronics	C26 - Manufacture of computer, electronic and optical products	84,074*	C2651 Manufacture of instruments and appliances for measuring, testing and navigation, C2670 Manufacture of optical instruments and photographic equipment
Transport and Defence: Auto components	C29 - Manufacture of motor vehicles, trailers and semi-trailers	234,398	C2930 Manufacture of other parts and accessories for motor vehicles: Airbags, car body panels, seat frames, car steering components and wheels
Transport and Defence: Aerospace components	C30 - Manufacture of other transport equipment	49,129*	C3030 Manufacture of air and spacecraft and related machinery: Landing gears, engine for aircraft, mirrors for satellites
Energy application	C26 - Manufacture of computer, electronic and optical products	84,074*	C2651 Manufacture of instruments and appliances for measuring, testing and navigation
Industrial components: Moulds	C28 - Manufacture of machinery and equipment n.e.c.	200,138*	C2823 Manufacture of machinery for metallurgy ceramic
Industrial components: Metal	C24 - Manufacture of basic metals	63,700	C2420 Other non-ferrous metal production: Bar, plate, rod, tube, and customized forms

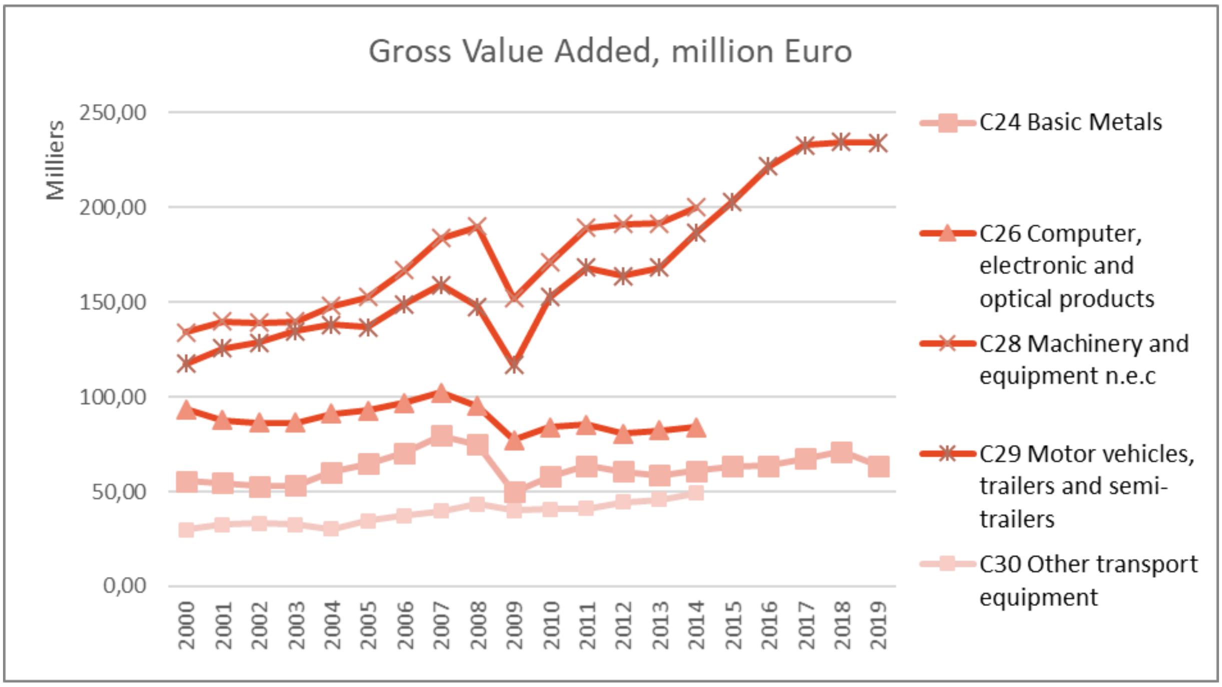

Figure 13. Gross Value Added (€millions) added per 2-digit NACE sector over time (Eurostat, 2022)

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SUBSTITUTION

Substitution of beryllium always leads to a loss of performance.

No other alloys offer the same combinations of copper-beryllium alloys, aluminium-beryllium alloys or pure beryllium properties. In all cases, there is a reduction in performance.

Alternate materials for copper-beryllium alloys may include (BeST, 2016a):

- Copper nickel silicon alloys (Corson alloys)
- Copper iron alloys
- Copper titanium alloys
- Copper Nickel Tin Spinodal Alloys (Cu-Ni-Sn)
- Phosphor bronzes (Cu-Fe-P)
- High Performance Bronzes (Cu-Pb-Sn + Al / Fe / Mn)

Alternate materials for the mechanical properties provided by beryllium metal could include (BeST, 2016a):

- Titanium alloys
- Magnesium alloys
- Aluminium alloys
- Carbon fibre composite

Alternate materials for the thermal properties provided by beryllium metal:

- Aluminium metal matrix composites with Silicon Carbide / Boron Nitride
- Carbon Reinforced Composites

Table 6. Uses and possible substitutes

Use	Percentage*	Substitute	Comment on substitute**
Electronic and telecommunications equipment	42%	Possible substitutes include: • Copper nickel tin alloy • Titanium-copper alloy • Copper nickel silicon alloy • Copper lead tin alloy • Aluminium / Lead / Manganese • Copper Iron Phosphorous alloy • Copper Tin Phosphorous alloy • Silicon • Boron nitride	Reduced performances Similar costs
Transport and Defence: Vehicle electronics	17%	Possible substitutes include: • Copper zinc alloy • Copper tin alloy • Copper nickel tin alloy • Copper lead tin alloy • Aluminium / lead / manganese • Copper iron phosphorous alloy • Copper nickel silicon alloy	Reduced performances Similar costs
Transport and Defence: Automobile components	17%	Possible substitutes include: • Aluminium alloys • Magnesium alloys • Aluminium metal matrix composites	Similar costs, similar performance

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		• Titanium alloys • Carbon reinforced composites	
Transport and Defence: Aerospace components	10%	Possible substitutes include: • Copper nickel tin alloy • Aluminium alloys • Aluminium metal matrix composites • Titanium alloys • Magnesium alloys • Carbon reinforced composites	

***EU end use share of Beryllium (SCRREEN, 2019 & 2021; SCRREEN EC Draft Data 2025-30; BeST, 2019)**

**** SCRREEN draft EC Data 2023-25**

The share of applications where beryllium can be substituted by these materials is less than 10%, especially for some applications in the defence, transportation and energy sector.

In parallel to substitution, reduction in the quantity of beryllium used in applications is also not feasible, since in practice beryllium is only used where necessary. Furthermore, the most prevalent use of beryllium occurs in copper-beryllium alloys, which only contain between 0.2% – 2% of beryllium (BeST, 2019c).

SUPPLY

EU SUPPLY CHAIN

The flows of beryllium through the EU economy are demonstrated in Figure 14. The EU has only limited involvement in the supply chain of beryllium for the manufacturing of products made of pure beryllium and copper-beryllium (CuBe) alloys. The supply chain of beryllium in the EU is summarised as follow:

The extraction and processing stage of beryllium takes place outside the EU. There are no known reserves of beryllium in the EU and no beryllium ores and concentrates are imported into the EU. Primary beryllium is processed into beryllium oxides and hydroxides outside the EU (Bio Intelligence Service, 2015).

Over the years 2012-2016, the import reliance of the EU on beryllium has been estimated at 100%. The EU entirely depends on imports of processed and semi-finished products, mainly under the form of beryllium master alloys and alloys (around 30 tonnes of beryllium per year), beryllium metal (around 5.6 tonnes of beryllium per year), and beryllium oxide (around 1.9 tonnes). There is no production of alloys or metal but reprocessing (rolling, stretching, slitting, cutting) of imported strips and bars (BeST, 2019a; Bio Intelligence Service, 2015). Some beryllium ceramics are produced in the EU out of imported beryllium oxides. The European industry uses these processed materials to manufacture various finished products. Some beryllium-copper alloy strip, rod, bar and plate products are produced in France, Germany and Switzerland.

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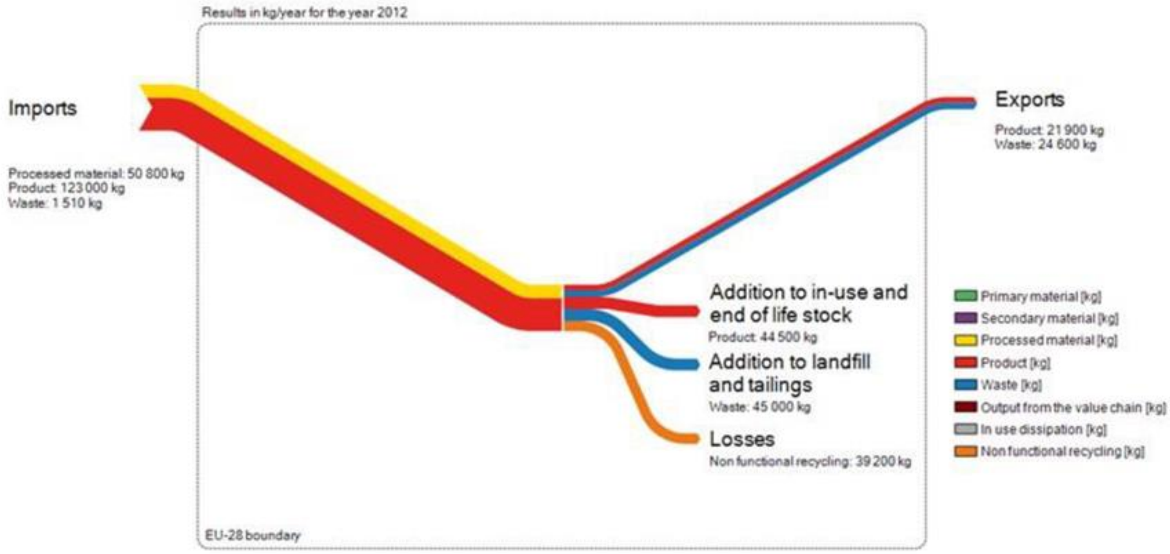

Figure 14. Simplified MSA of beryllium flows in the EU in 2012 (BIO Intelligence Service, 2015)

During the manufacture step, the European industry generates a lot of scrap (around half of the beryllium input) which is generally sent back to suppliers outside Europe for recycling (Freeman, 2016). The EU also imports a large quantity of finished products containing beryllium (Bio Intelligence Service, 2015). One company in France is known to treat Beryllium-copper alloy scrap to produce new alloy (Sundqvist Ökvist et al. 2018).

The beryllium contained in the waste ends up in landfill or is down-cycled with a large magnitude material stream. However, there is no post-consumer functional recycling of beryllium in Europe and in the world (Bio Intelligence Service, 2015).

There are no updated Eurostat data available concerning the imported amount of beryllium in EU. According Worldbank database, about 10 tonnes of beryllium (product code: 811219) were imported in EU in 2019 (worldbank, 2019).

SUPPLY FROM PRIMARY MATERIALS

GEOLOGY, RESOURCES AND RESERVES OF BERYLLIUM

GEOLOGICAL OCCURRENCE

Beryllium is a relatively rare element with a concentration of about 2.8-3 ppm in the earth's crust, and 2.1 ppm in the uppercrust (Rudnick, 2003). It is concentrated in some minerals, predominantly in beryl and bertrandite (BeST, 2016b; European Commission, 2014).

Until the late 1960s the only beryllium mineral commercially exploited was beryl ($Be_3Al_2Si_6O_{18}$). Beryl contains between 3 and 5% of beryllium but the material is harder than bertrandite ($Be_4Si_2O_7(OH)_2$) leading

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to difficulties to refine into beryllium. Today the most important commercial beryllium mineral is bertrandite (over 75% of mining operations) which is extracted from ores containing 0.3-1.5% beryllium. Beryllium is also extracted from beryl as a by-product of small-scale emerald gemstone mining operations in Brazil, Argentina and other countries in South America and Africa (BeST, 2016b).

GLOBAL RESOURCES AND RESERVES

About 60% of beryllium resources occur in the United States and mainly in Spor Mountain area in Utah, where the epithermal deposit contains a large bertrandite resource, which is being mined. Proven and probable bertrandite reserves in Utah total about 20,000 tonnes of contained beryllium. World beryllium reserves are not available. The world's identified resources of beryllium have been estimated to be more than 100,000 tons. Apart Spor Mountain area in Utah, other important resources of beryllium in US exist in: McCullough Butte area in Nevada, the Black Hills area in South Dakota, the Sierra Blanca area in Texas, the Seward Peninsula in Alaska, and the Gold Hill area in Utah (USGS, 2022).

EU RESOURCES AND RESERVES

The Minerals4EU reports no data on beryllium resources and reserves in the EU (Minerals4EU, 2019).

According to experts, there are very limited resources (about 12 tonnes) of beryllium in Europe. (Bio Intelligence Service, 2015). There are known resources of beryllium in several locations in Europe, notably the Bordvedaga deposits at Rana in the north of Norway. Smaller deposits are also known to exist in Germany, Czechia and Ireland (Bio Intelligence Service, 2015). These resources are in the form of beryl crystals and are usually found in a matrix of granitic pegmatite rock.

According to a report by Lauri, L. et al. (2018), the following countries in Europe are known to have resources of beryllium, though most of them are not of economic significance:

• Austria. Beryl-bearing complex pegmatites are known to be present in various locations in Austria. Only two deposits (Spittal/Wolfsberg feldspar deposit and Markogel granite quarry) are reported to have extracted in the past, but no data for beryllium is given.

• Czechia. Rare-metal pegmatites and granites containing contain beryl as an ore mineral are known to exist, but only two occurrences (Rasovna Maršíkov and Vetrny Vrch) report beryllium as the main commodity.

• Finland. Beryllium minerals are known to be present in Finland. Beryllium contents are reported from four deposits in Finland. The resource estimate available is available for the Rosendal deposit (South-West of Finland) with 206.85 tonnes of beryllium.

• France. According to BRGM (2016), there are some known resources in France in 6 deposits, including one evaluated at 2,400 tonnes of contained beryllium (BRGM, 2016). Tens of granite intrusions and granitic pegmatites with beryllium minerals are known in France, mostly located in Bretagne in (North-West of France) and in the Pyrenees (Lauri et al., 2018)

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• Germany. Beryllium minerals are present in many granites and granitic pegmatites. No records available for beryllium mining (Lauri et al., 2018)

• Italy. Some occurrences of beryllium associated with granitic pegmatites are known, but they are mainly with mineralogical interest.

• Portugal. Portugal has had deposits in complex granitic pegmatites containing beryl in addition to Sn, Nb, Ta, and W minerals. Small-scale beryllium production took place in the mid-1900s from several deposits.

• Spain. Four beryllium-bearing occurrences are listed. Three of these are granitic pegmatites that contain beryl as an ore mineral. One occurrence (Galiñeiro) is associated with peralkaline gneisses and is currently of interest in terms of REE exploration.

• Sweden. One beryllium deposit and closed mine, Selvitberget, was reported but there is no resource estimate available

• In addition, the area of Högtuva in the middle of Norway, Nordland County was reported to host several spatially restricted Be beryllium deposit with phenakite as the main ore mineral (Schilling, et. al., 2015).

However, according to experts, there are no reserves of beryllium in Europe (Bio Intelligence Service, 2015).

WORLD AND EU MINE PRODUCTION

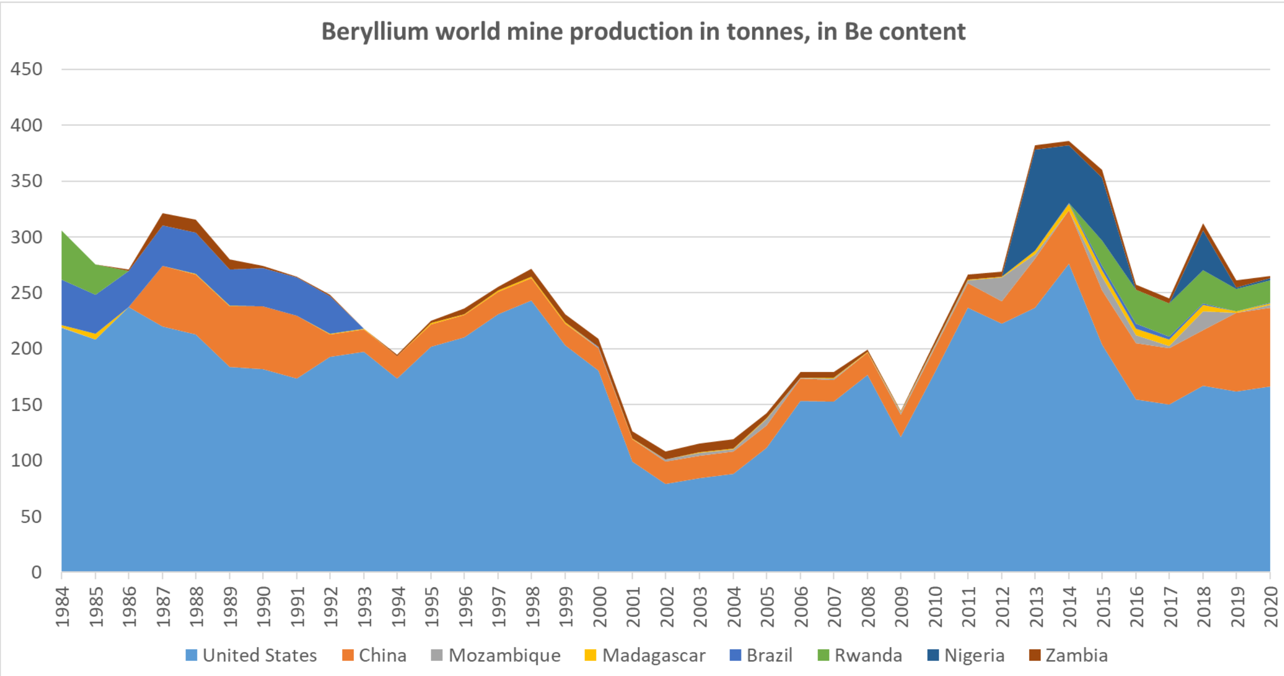

Figure 15. Global production of beryllium concentrate since 1984 (WMD, since 1984), in Be content (4% of the concentrate)

The global produced amount of primary raw beryllium-containing concentrate since 1984 is presented in Figure 15. As it can be observed, USA and China are only major producers since 2002. Beryllium concentrate

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production in USA and China represented the 68% and the 29%, respectively of the total global production in 2020 (WMD, since 1984). The Be content in the concentrate is estimated at 4%.

Worldwide production of refined beryllium (in alloys, metal or ceramics) in 2021 is estimated at 256 tonnes. The global produced amount of metallic beryllium since 2000 is shown in Figure 16. As in case of beryllium concentrate, USA and China are main producers of refined beryllium (66% and 27% of the global amount in 2021). A minor beryllium production, less than 3% of the global, is taking place in Uganda (USGS, since 2000).

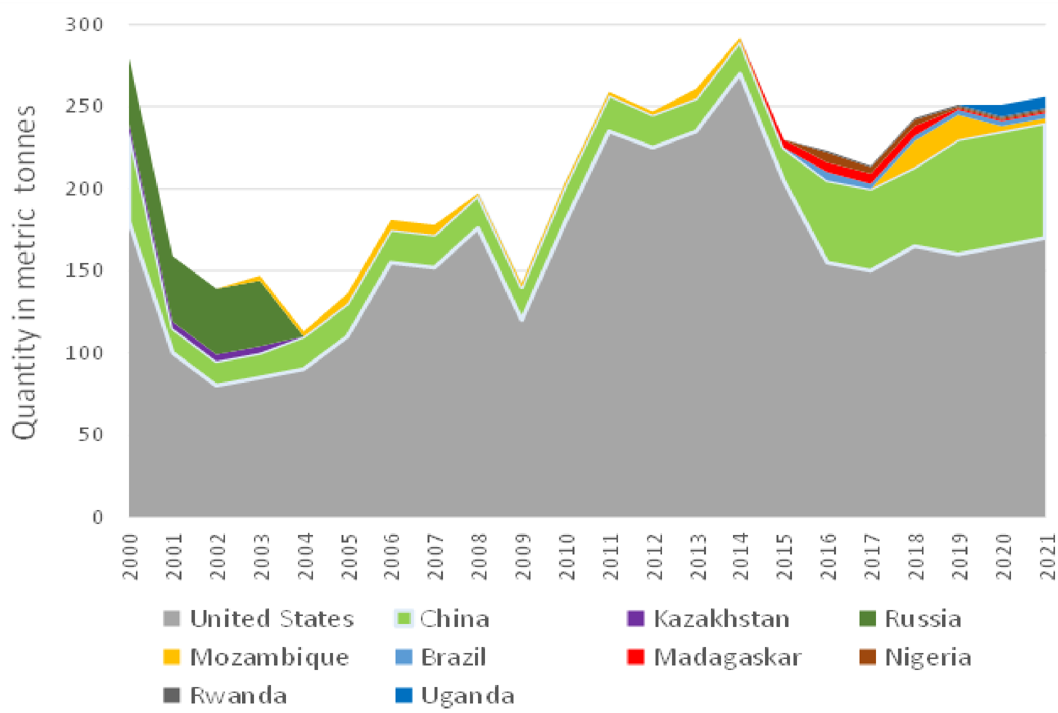

Figure 16. Global production of refined beryllium since 2000 (USGS, since 2000), in Be content

OUTLOOK FOR SUPPLY

The Spor Mountain mine is the largest producer of beryllium in the world, accounting for approximately 63% of the world's annual production in 2020. The proven and probable reserves at Spor Mountain are estimated to be enough to maintain mining at current production levels for another 75 years. Beryllium production in Spor Mountain is stabilized the last years (2019, 2020) around 150 tonnes (Rupke et al. 2022). Refined beryllium demand is forecasted to be increased by a rate of 2.12% util 2030 (coherentmarketinsights, 2022), however there is no any published research describing the relative supply rate during the same period.

SUPPLY FROM SECONDARY MATERIALS/RECYCLING

POST-CONSUMER RECYCLING (OLD SCRAP)

There is no known post-consumer functional recycling of beryllium in Europe and in the world. Beryllium is not recycled from end finished products (BeST, 2016b), therefore the end of life recycling input rate is 0%. The

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recuperation of pure metal of beryllium from end finished products is extremely difficult because of the small size of components and the tiny fraction of beryllium contained in appliances (less than 40 ppm in appliance having the highest amount of Be) (BeST, 2016b). The beryllium contained in the waste usually ends up in landfill. The stock accumulated in landfill in the EU over the last 20 years is estimated at around 610 tonnes of beryllium content (Sundqvist Ökvist et al. 2018).

INDUSTRIAL RECYCLING (NEW SCRAP)

Beryllium can be recovered from new scrap generated during the manufacture of beryllium products and from old scrap. Almost all the new scrap (between 94% and 100%) is sent back to the producer and recycled (Freeman, 2016). In 2013 secondary beryllium production from new scrap recycling was between 100 and 135 tonnes, i.e. about 20% of global demand (BRGM, 2016).

There are some companies that recycle beryllium new scrap, for example Monico Alloys and Materion (United States). In the EU, NGK Berylco (France), located near Nantes, is known to treat Beryllium-copper alloy scrap to produce new alloy. (Sundqvist Ökvist et al. 2018).

REFINING OF BERYLLIUM

The extraction of beryllium from its main source's beryl and bertrandite involves several stages. After mining the ores, they are first converted to an acid-soluble form. To obtain comparatively pure beryllium hydroxide or oxide, and in a further step beryllium chloride or fluoride, complex chemical processes are used. These halogenides are then reduced to metallic beryllium with other metals or by melt electrolysis. The beryllium metal obtained is subject to one or more refining processes and finally to further treatment. (BeST, 2016b).

More specifically, three different metallurgical routes are followed according to the final product to be produced: metallic beryllium, beryllium oxide and beryllium into alloy (Figure 17). In case of metallic beryllium powder production, the procedure comprises the dissolving of $Be(OH)_2$, BeO, and/or beryllium scrap in ammonium bifluoride to form an ammonium beryllium fluoride (ABF) solution $[(NH4)_2BeF_4]$. This solution is then purified, evaporated, and crystallized to form ABF salt. In the pebbles plant, the ABF salt is fed into a fluoride furnace and heated to form glassy beryllium fluoride (BeF_2). Subsequently, BeF_2 is reduced with magnesium in a reduction furnace resulting in metallic beryllium pebbles within a magnesium fluoride (MgF_2) matrix.

Beryllium industry in US is fully looped comprising: mining, ore processing, manufacture, sale and recycling of beryllium-bearing products. Japan does not extract beryllium ores but refine it from imports (Freeman, 2016). Kazakshstan refines its beryllium from stockpiled ores and will most likely to continue to do so in the future (BeST, 2019c).

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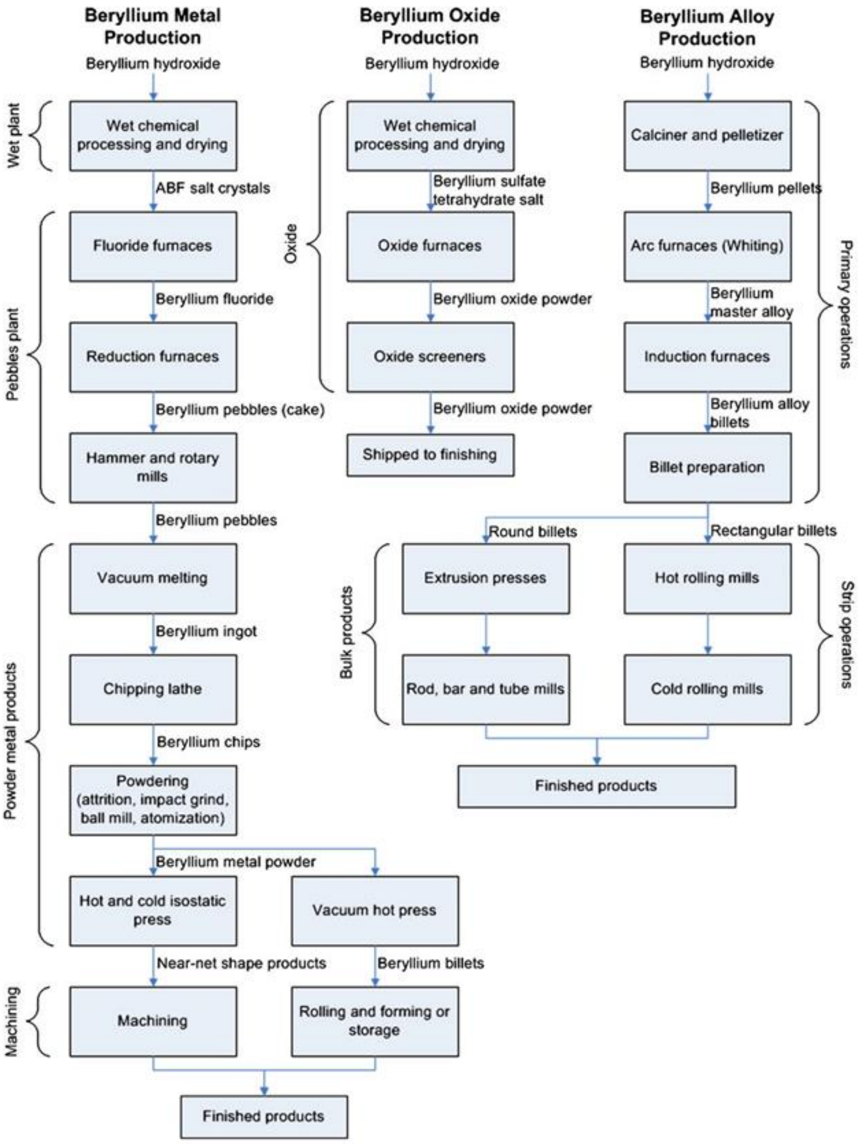

Figure 17. Metallurgical processing of beryllium hydroxide for the production of: metallic beryllium, beryllium oxide and beryllium alloys (Virji et al. 2011).

OTHER CONSIDERATIONS

HEALTH AND SAFETY ISSUES

The use/ban of Beryllium is restricted under REACH Regulation (EC) No 1907/2006 Annex XVII (Deutsche Forschungsgemeinschaft and Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area, 2002). In REACH Regulation (EC) No 1907/2006 Annex XVII, Point 28 states that the substance shall not be placed on the market or used as a substance or as a constituent of other substances or in mixtures for supply to the general public when the concentration of the substance or mixture reaches or exceeds the concentration limits according to the CLP Regulation. When placing the substance or mixture on the market

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for professional users, the supplier shall ensure that the packaging of such substances and mixtures is marked with the label "Restricted to professional users."

The EC occupational exposure limit defined in the Directive 2019/983/EU sets an 8-hour limit value of 0.001 mg/m³ (inhalable fraction). This substance can cause sensitisation of the skin and of the respiratory tract with a limit value of 0.0006 mg/m3 until 11 July 2026. In addition, the Directive 2012/18/EU (Seveso III)[2] states that this substance is considered a Category 2, acute toxic (all exposure routes) or Category 3 (inhalation exposure route) or Category 3 (oral route if neither acute inhalation toxicity classification nor acute dermal toxicity classification can be derived).

The International Agency for Research on Cancer (IARC) and the EU Carcinogens and Mutagens Directive (Directive 2004/37/EC) and the EU's Regulation on Classification, Labelling and Packaging of substances and mixtures (Regulation (EC) No 1272/2008) recognizes beryllium and beryllium compounds as a Group 1 carcinogen (Niu et al. 2022; 'EU Regulations' 2016). In addition, occupational exposure to beryllium dust and fumes occurs in all phases of metal extraction and refining. According to the International Labour Organization, between 1% and 15% of workers using beryllium are exposed to unsafe levels (Niu et al. 2022).

ENVIRONMENTAL ISSUES

No environmental issues were found in the scientific literature review. In addition, no LCAs studies could be found related to any life cycle stage or specific use of the material during the scientific literature review.

NORMATIVE REQUIREMENTS RELATED TO THE USE AND PROCESSING OF BERYLLIUM

Technical rules for the use of Beryllium can be found in the GESTIS Substance database[3]. In addition, Beryllium is included under the German regulation of accident insurers[4] for the use of respiratory protective equipment published in November 2021. International limit values for Beryllium and inorganic compounds[5], Beryllium fluoride[5], Beryllium hydroxide[5] and Beryllium oxide[5] can be found in the GESTIS international limit values database.

SOCIO-ECONOMIC AND ETHICAL ISSUES

ECONOMIC IMPORTANCE OF BERYLLIUM FOR EXPORTING COUNTRIES

Globally the beryllium economy is very small (about 0.0002% of the total world trade market). The importance of this market is also anecdotic for the two main producing countries (Kazakhstan 0.03% and USA 0.0014% of their total export trade value) (COMTRADE, 2020).

[2] See https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0018&from=EN
[3] See https://gestis-database.dguv.de/data?name=008020
[4] See https://www.baua.de/DE/Angebote/Rechtstexte-und-Technische-Regeln/Regelwerk/TRGS/TRGS-900.html
[5] See https://limitvalue.ifa.dguv.de/WebForm_ueliste2.aspx

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SOCIAL AND ETHICAL ASPECTS

No specific issues were identified during data collection and stakeholders' consultation.

RESEARCH AND DEVELOPMENT TRENDS

RESEARCH AND DEVELOPMENT TRENDS FOR LOW-CARBON AND GREEN TECHNOLOGIES

a. R&D trends in terms of emerging LCGT

- Beryllium as construction material for nuclear fusion reactors (Iter 2022). *The nuclear fusion research reactors JET and ITER use inner walls made of beryllium and tungsten metals.*

b. R&D trends in terms of emerging application of RM in already existing LCGT

- No research and development trends could be identified in the context of beryllium use in already existing LCGT.

OTHER RESEARCH AND DEVELOPMENT TRENDS

No projects were available.

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