6 BORATES

6.1 Overview

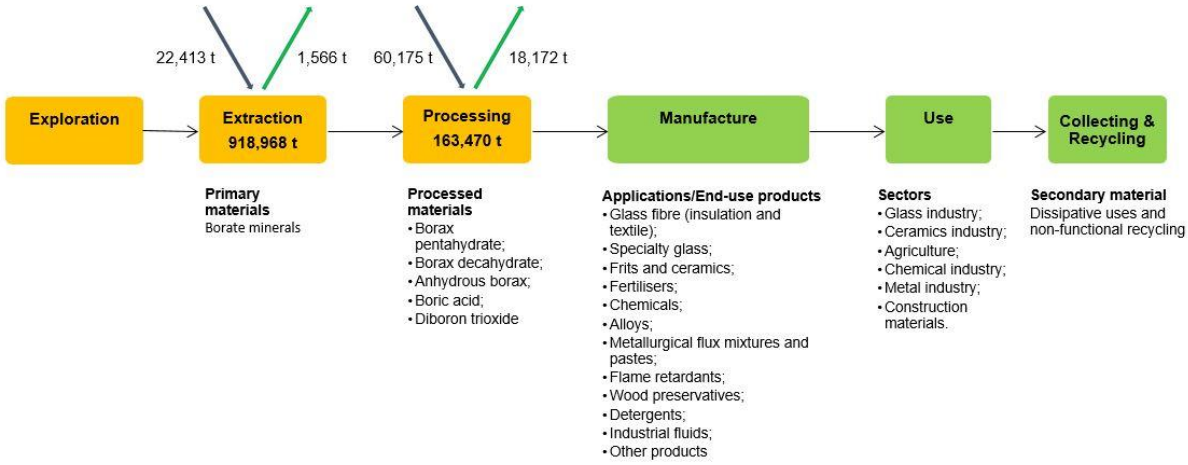

Figure 70: Simplified value chain for borates for the EU, averaged over 2012-2016[37]

Borates are naturally occurring minerals containing boron (B, atomic number 5). The industry defines borates as any compound that contains or supplies boric oxide (B_2O_3). Borates are thus inorganic salts of boron and refer to a large number of mineral and chemical compounds that contain borate anions. They have metabolising, bleaching, buffering, dispersing, and vitrifying properties.

For this assessment, borates at both extraction (natural borates) and processing stage (refined borates) are analysed. At mine stage, borates are assessed in the form of natural borates and their concentrates (CN8 code 25280000, B content 20%).

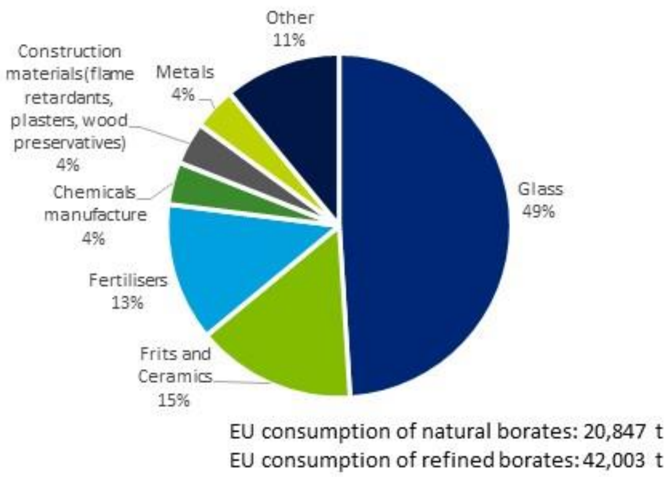

Figure 71: End uses (IMA Europe 2016) and consumption (average 2012-2016) of borates in the EU (Eurostat Comext 2019) (WMD 2019) (UN Comtrade 2019) (WITS 2019).

At the processing stage, the boron compounds considered are boric acid and diboron oxide, borax and anhydrous borax. The trade codes used for EU trade of refined borates are

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

Diboron trioxide (CN8 28100010, B content 31%); Oxides of boron and boric acids excl. diboron trioxide (CN8 28100090, B content 17%); Anhydrous disodium tetraborate "refined borax" (CN8 28401100, B content 21%); Disodium tetraborate penthahydrate (CN 28401910, B content 15%); Disodium tetraborate decahydrate "refined borax" (CN8 28401990, B content 9%). (Eurostat Comext, 2019)

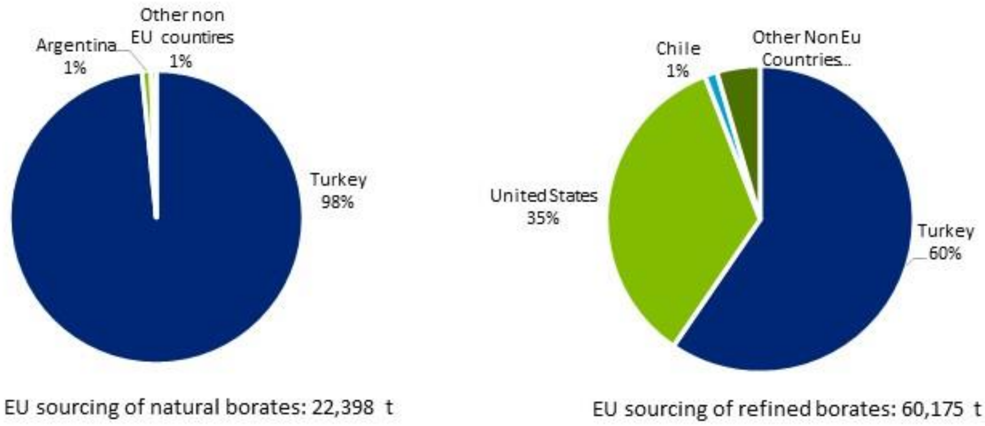

Figure 72: EU sourcing of natural borates (left) and refined borates (right) (average 2012-2016) (Eurostat Comext 2019) (WMD 2019) (UN Comtrade 2019) (WITS 2019).

The trade codes used are: Oxides of boron, boric acids (HS6 281000, B content 17%); Anhydrous disodium tetraborate "refined borax" (HS6 284011, B content 21%); Disodium tetraborate, not anhydrous (HS6 284019, B content: 12%). (Eurostat Comext, 2019)

All quantities are expressed in boron content, which is calculated as the boron atomic weight divided by the specific molecular weight.

The world market value of boron minerals (natural borates) production is estimated at EUR 1.25 billion. Turkey and the US dominate global exports in natural and refined borated respectively, while China is the leading importing country. The demand for borates depends on the growth of the global economy and the rise of living standards due to the nature of end uses.

After being relatively flat for many years, borate prices had a downward trend between 2005 and 2015. The average EU imports unit value for natural borates in 2018 was EUR 285 per t and for refined borates (borax pentahydrate and boric acid) EUR 360 per t of B_2O_3 (boric oxide) content. (Eurostat Comext, 2019)

The total EU consumption of borates between 2012 and 2016 was around 62,850 t per year, comprising of 20,847 t per year natural borates (33%) and 42,003 t per year of refined borates (67%). The EU is entirely dependent on imports of borates for its consumption as there is no domestic production. The imports of natural borates to the EU come almost entirely from Turkey (98%). Turkey (60%) and the US (35%) are the main sources of EU imports of refined borates. Import reliance is 100% for both natural and refined borates (Eurostat Comext 2019).

Borates are essential ingredients in a variety of household and commercial products including: insulation fiberglass, textile fiberglass and heat-resistant glass; detergents, soaps and personal care products; ceramic and enamel frits and glazes, ceramic tile bodies; agricultural micronutrients; other uses including wood treatment, polymer additives and pest control products. Borates can be substituted with other materials in soaps, wood preservatives, and detergents (IMA Europe 2016) (SCRREEN workshops 2019).

The known world borate reserves are around 1,100 million t of contained boron(USGS 2019c). 75-80% of the world's boron reserves are located in Turkey (Helvacı 2017). No boron deposits are located in the EU.

The world annual production of natural borates is about 4,594,840 t of boron minerals (around 918,968 t in B content), averaged over 2012 to 2016. Turkey is the leading producer with a share of 43% of world mine production, followed by the US, which accounts for one-quarter (25%) (WMD 2019). Concerning refined borates, there is no official data on the world output. According to trade data relevant to oxides of boron and boric acids (B content 17%), anhydrous disodium tetraborate (refined borax) (B content 21%), other than anhydrous disodium tetraborate (refined borax) (B content 12%), it can be inferred that the US supplies the majority of processed borates (67%), followed by Chile (9%) (UN Comtrade 2019). There is no production of natural or refined borates in the EU.

Given the type of applications, borates are not recyclable. Glass recycling is considered non-functional for boron, and the end-of-life recycling input rate (EoL-RIR) is less than 1% (BIO Intelligence Service 2015a) (SCRREEN workshops 2019).

A role for borates in the implementation of the European Commission's long-term strategy for a climate-neutral economy by 2050, is identified in wind turbines through neodymium-iron-boron magnets and energy efficiency in buildings through insulation fibreglass.

Borate substances have been listed as substances of very high concern on the candidate list of the EU's REACH Regulation, and prioritisation has been given to some for authorisation under REACH (ECHA 2019a).

6.2 Market analysis, trade and prices

6.2.1 Global market

The world production of boron minerals in 2017 was about 4,594,840 t (WMD 2019) worth approximately EUR 1.25 billion[38]. Borates mine production declined over the past decade at an annual compound rate of -1.9%, mainly due to decreasing production from Argentina and Peru. Turkey and the US remain the largest producers.

Two companies dominate the global market by having a share of over 75%; Eti Maden which controls all borate deposits across Turkey and US Borax owned by Rio Tinto, which operates the Boron mine in California. It is reported that the market is not going to diversify any time soon as exploration is minimal by other companies (McCormick 2018). However, at current levels of consumption, world resources are adequate for the foreseeable future (USGS 2019b).
According to UN Comtrade trade data for 2016 (see Figure 73)Turkey dominates the export market of natural borates with a share of 71% of the total value, while the main importing country is China (38% of total imports by value). In terms of volume, the cross border trade (imports) of natural borates amounted to about 1 million t in 2016. For refined borates (Figure 74), the US holds the largest share of the market with 64% of the total exports, whereas China is again the leading importer (33% of total imports by value).

[38] Estimation based on the average unit value of EU imports in 2016 (EUR 290 per tonne of natural borates) and the global production in 2016.

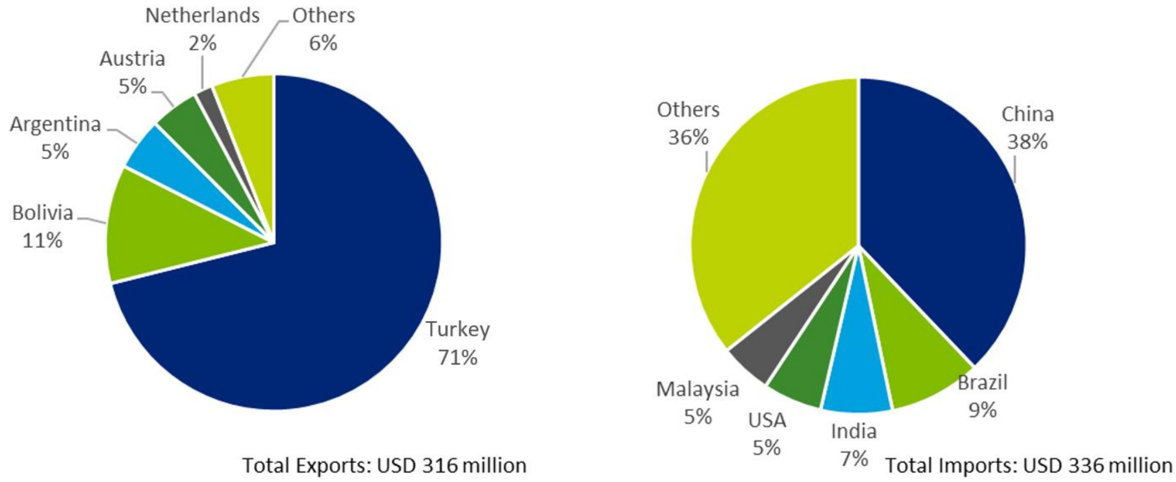

Figure 73: Top-5 natural borates world exporters (left) and importers (right) in 2016 by value. (UN Comtrade 2019)

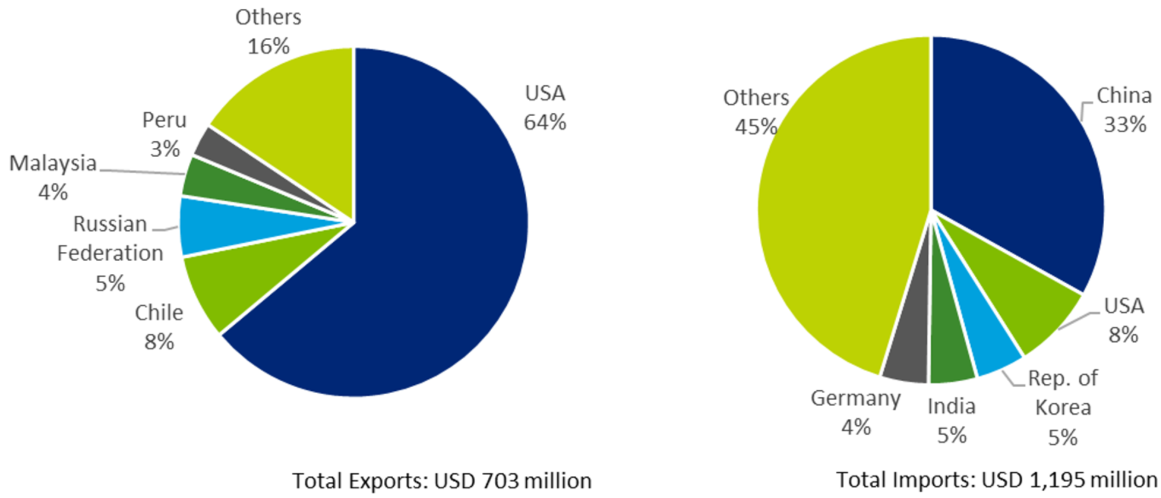

Figure 74: Top-5 refined borates world exporters (left) and importers (right) in 2016 by value. (UN Comtrade, 2019)

Bolivia, which accounts for about 3% of global natural borates production, applies a fiscal tax on exports of natural and refined borates of 0.05% of the gross export value. Argentina, which holds an 8% share of world natural borates production, lifted in 2016 an export tax of 10% for natural borates, and at the end of 2015 an export tax of 5% for products of refined borates (OECD 2019). However, the Government of Argentina announced the re-establishment of export duties on September 2018 on all tariff lines including codes HS 252800, HS 281000 and HS 284019 (Global Trade Alert 2018).

6.2.2 Outlook for supply and demand

The demand for borates tends to be associated with the growth of the global economy due to the composition of end-use markets (Rio Tinto 2014) (McCormick 2018). Demand is expected to remain relatively stable in the short term, as the strong demand growth in some market segments is partially offset by excess inventory build in the value chains of others (Rio Tinto 2015).

The medium- to long-term demand in the borates market is linked to wealth and living standards. Urbanisation, energy and food supply are the key drivers for growing demand in the future (Rio Tinto 2014) (Rio Tinto 2018b). Consumption of borates used in fertilisers is anticipated to increase supported by the requirement for ever-greater crop yields. The rising demand for building insulation due to improvements in the building standards drives fibreglass - and thus borates - demand. Growing economies and urbanisation fuel demand for borates in glass applications, e.g. LCD televisions and electronics, which contain borosilicate glass and textile fiberglass (McCormick 2018) (Rio Tinto 2014). The rising demand for borates in the coming years is expected mostly by the agricultural, ceramic and glass sectors in Asia and South America (USGS 2018a).

In the supply side, the Jadar lithium-borate deposit in Serbia with the previously unknown mineral jadarite as the main commercial mineral was discovered by Rio Tinto in 2004. The deposit contains 21 million t of B_2O_3 as an equivalent borate product resource. The Jadar project could potentially supply a significant proportion of global demand for borates. The pre-feasibility study is on-going for a mine and processing facility, and production could commence by 2023-2024 (Rio Tinto 2018a) (Rio Tinto 2017).

The qualitative outlook for borates supply and demand is shown in Table 31.

Table 31: Qualitative forecast of supply and demand of borates

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
Borates	x		stable	+	+	stable	+	+

6.2.3 EU trade

The annual EU imports of natural borates were 22,410 t and the imports of refined borates 60,175 t, on average for the 2012-2016 period (in B content). The EU exports of natural and refined borates were approximately 1,565 t and 18,170 t respectively in the same period (in B content). Thus, the average net imports from 2012 to 2016 are about 20,850 t for natural borates (Figure 75), and around 42,000 t for refined borates (Figure 76) (Eurstat Comext 2019) (WITS 2019). As shown in Figure 75 and Figure 76, the main trend observed in the period 2012-2016 is the sharp decrease of net imports of refined borates in 2015 and 2016.

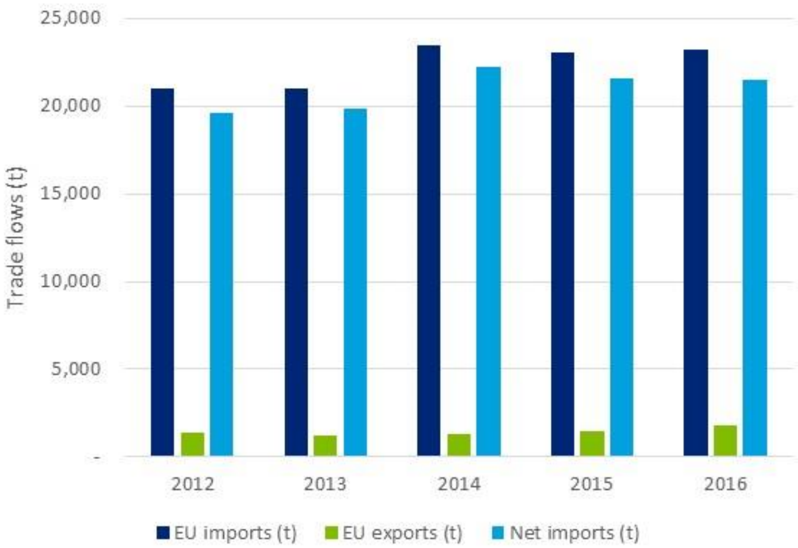

Figure 75: EU trade flows for natural borates (in B content). (Eurostat Comext 2019)

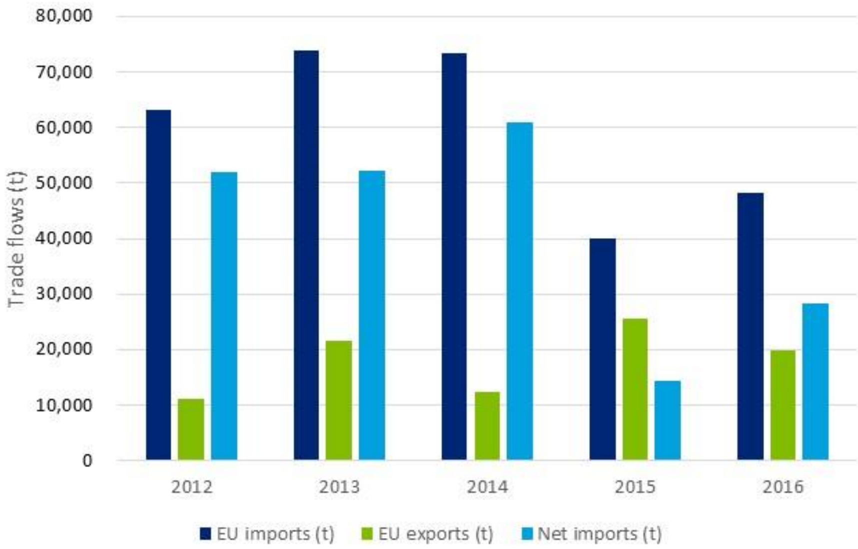

Figure 76: EU trade flows for refined borates (in B content) (Eurostat Comext 2019) (WITS 2019)[39]

Figure 77 shows the EU's major trading partners for imports of natural and refined borates. Turkey is almost the single supplier of the EU for natural borates, with 98% of the total imports on average over the 2012-2016 period. Likewise, Turkey is the dominant exporting country to the EU for refined borates, covering 60% of the total imports on average over the 2012-2016 period (Figure 77). The US is the second source country for EU imports of refined borates with a substantial share of 35%.

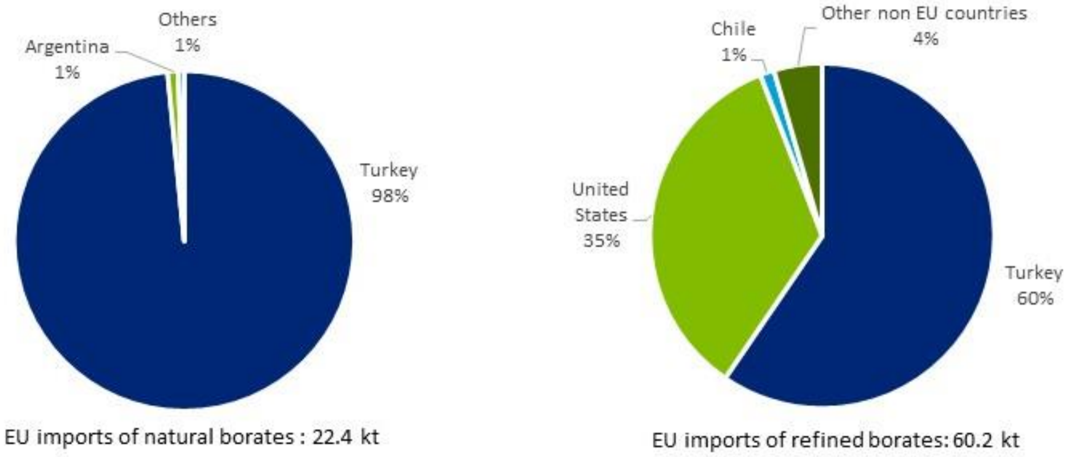

Figure 77: EU imports of natural (left) and refined borated (right). Average 2012-2016 (in B content) (Eurostat Comext 2019) (WITS 2019)[40]

[39] EU imports of refined borates from US and Turkey

[40] EU imports of refined borates from US and Turkey

The EU and Turkey have a Customs Union agreement in force since 1996 (European Commission 2019).

6.2.4 Prices and price volatility

Borates are priced and sold based on their boric oxide content (B_2O_3), which varies by ore and boron compound and by the absence or presence of calcium and sodium (USGS, 2019a). Prices for the various refined products reflect the energy cost of refining and drying (Carpenter and Kistler 2006).

Assessments of market prices are published by the United States Geological Survey (US unit value) and price reporting agencies. In January 2019, Fastmarkets Industrial Minerals announced the discontinuation of its borates/boron minerals price assessments due to limited interest in the markets (prices referred to natural and refined borates FOB South America ports) (Fastmarkets IM 2019).

Prices had been stable in the 1990s up to mid-2000s, reflecting a balance between supply and demand in the market (Carpenter and Kistler 2006). Since then, borate prices are following a downward trend as it is demonstrated in Figure 78.

Figure 78. Borates historical price volatility[41] in the United States (indexed to the 1998 unit value), yearly average (in USD/t of B_2O_3 content) (USGS 2017).

The unit value of EU imports for natural borates is relatively stable since 2010 ranging between EUR 243 and 290 per t in the period 2010-2018 as an annual average (see Figure 79). For the most commonly traded refined borates (boric acid and borax pentahydrate), it is noteworthy an increase in the imports unit value from 2010 to 2013 when the average imports unit value of boric acid and borax pentahydrate reached peaked at EUR 490 per t of boric oxide (B_2O_3), followed by a generally downward trend up to 2018. In 2018, the average imports unit value of boric acid and borax pentahydrate was EUR 360 per t of B_2O_3.

[41] The unit value in the US is defined as the estimated value of apparent consumption in U.S. dollars of one tonne of B_2O_3 content

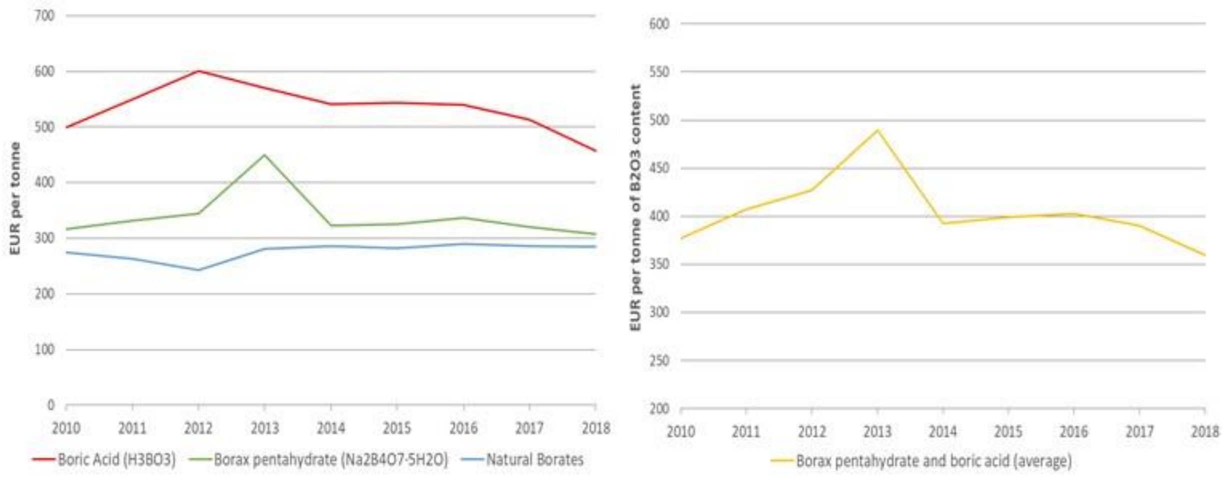

Figure 79. Unit value[42] of EU imports of borate commodities, yearly average (left in EUR per t, right in EUR/t of B_2O_3 content). (Eurostat Comext 2019)

6.3 EU demand

6.3.1 EU consumption

The total EU apparent consumption of borates between 2012 and 2016 was estimated at 62,850 t per year (B content). Natural borates account for one-third of the total consumption (20,847 t/y), and processed/refined borates for two-thirds (42,003 t). In terms of volume, the average annual consumption for the period 2012-2016 is 112,000 t for natural borates (Eurostat Comext 2019), and 301,000 t for processed/refined borates (WITS 2019). The EU is fully dependent on imports for its consumption (import reliance of 100%).

6.3.2 Uses and end-uses of borates in the EU

Borates are a key input material in the production of fibreglass insulation, textile fibreglass, borosilicate glass, ceramics and fertilisers. These applications account for over three-quarters of borates consumption. Borates also have several other applications within the construction, metallurgy and chemicals industries. The borates imported in the EU are mostly embodied in glass products. The second single most common application of borates imports is the supply to ceramics and frits industry followed by fertilisers. Other products are construction materials, abrasives, catalysts, coatings, detergents, etc. The EU end-uses of borates in 2012 are shown in Figure 80.

[42] Not corrected for inflation

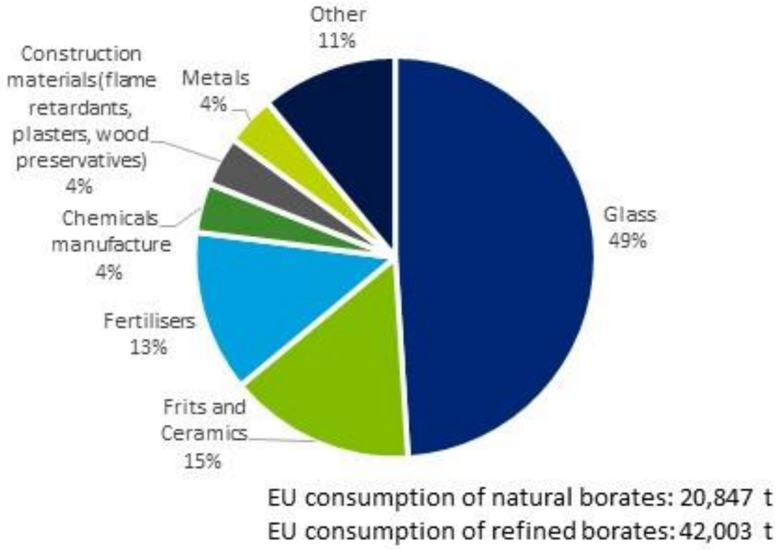

Figure 80: EU end uses in 2012 (IMA Europe 2016) and EU consumption of borates (average 2012-2016, in B content (Eurostat Comext 2019)(WMD 2019)(UN Comtrade 2019)(WITS 2019).

The end-use of borates are described below (BIO Intelligence Service 2015) (IMA Europe 2016) (USGS 2018) (SCRREEN workshop 2019):

• *Glass:* The glass industry dominates the demand for borates worldwide. Natural (e.g. colemanite concentrates, ulexite) or refined borates (e.g. borax pentahydrate, boric acid) can be added as raw materials during the manufacturing of glass depending on the application and the required quality. In Europe, borax pentahydrate is the dominant raw material for boron addition to the glass melt (BIO Intelligence Service 2015). The boron in borosilicate glass imparts increased mechanical strength and resistance to chemical corrosion, as well as improved resistance to high temperatures and thermal shocks due to a low coefficient of thermal expansion. In borosilicate glasses the B_2O_3 content typically ranges between 7% and 15% (Scalet et al. 2013), but can be as high as 30% (USGS 2018). Glass fibre production includes insulation glass fibre (glass wool) and continuous filament glass fibre (textile grade). E-glass composition typically ranges from 5% to 10% of B_2O_3 content (Scalet et al. 2013)(RPA 2008). Furthermore, boron addition to the glass melt facilitates the production process as it lowers the glass batch melting temperature, favours fiberisation and inhibits crystallisation of the glass.
Glass products can be grouped in two categories:

- *Insulation glass*: Insulation fiberglass (IFG) used in construction, vehicles, appliances and machinery for thermal and acoustic insulation;
- *Other glass (excl. insulation)*: Textile fiberglass (TFG) USED in the manufacture of composite materials (glass-reinforced plastics), and borosilicate glass used in heat-resistant glass cookware and glass panels (e.g. for oven doors), laboratory glassware, pharmaceutical packaging, light bulbs, solar panels, LCD screens etc.;

• *Frits and Ceramics*: Borates are essential ingredient to produce frits used by the ceramic industry in ceramic glazes and enamels for chemical, thermal cycling, and wear resistance;

• *Fertilisers*: Boron is an essential micronutrient for plant growth, crop yield and seed development. Although only low amounts of boron are required, its deficiency in soil can have severe effects on the crops;

• *Wood preservatives:* Borates are used to treat wood to ward off insects and other pests;

• *Detergents*: Borates are used in laundry detergents, household and industrial cleaning products. Borates enhance stain removal and bleaching, provide alkaline buffering, soften water and improve surfactant performance.

•*Chemicals (excl. Fertilisers, wood preservatives and detergents)*: Used for chemicals such as fire retardants;
•*Industrial fluids*: Used for metalworking fluids, and other fluids used in cars, antifreeze, braking fluid etc.;
•*Metals*: Boron is used as an additive for steel and other ferrous metals as its presence ensures higher strength at a lower weight.

Relevant industry sectors are described using the NACE sector codes in Table 32.

Table 32: Borate applications, 2-digit and examples of associated 4-digit NACE sectors, and value-added per sector (Eurostat 2019)

Applications	2-digit NACE sector	Value added of NACE 2 sector (M€)	Examples of 4-digit NACE sector(s)
Glass	C23 - Manufacture of other non-metallic mineral products	57,255	C2314 - Manufacture of glass fibres C2319 - Manufacture and processing of other glass, including technical glassware
Frits and Ceramics	C23 - Manufacture of other non-metallic mineral products	57,255	C2331 - Manufacture of ceramic tiles and flags
Fertilisers	C20 - Manufacture of chemicals and chemical products	105,514	C2015 - Manufacture of fertilisers and nitrogen compound
Chemicals manufacture	C20 - Manufacture of chemicals and chemical products	105,514	C1610- Sawmilling and planing of wood
Construction materials (flame retardants, plasters, wood preservatives)	C20 - Manufacture of chemicals and chemical products	105,514	C2059- Manufacture of other chemical products n.e.c.
Chemicals manufacture	C20 - Manufacture of chemicals and chemical products	105,514	C2059- Manufacture of other chemical products n.e.c.
Metals	C24 - Manufacture of basic metals	55,426	C2410- Manufacture of basic iron and steel and of ferro-alloys

6.3.3 Substitution

Borates may be substituted in fibreglass (boron-free E-glass), or fibreglass insulation may be replaced itself by alternative materials such as cellulose, foams, and mineral wool (Tercero et al. 2018) (USGS 2019a). However, the extent of borates' use is a limitation in itself and, practically, there are no commercially available substitutes for fibreglass insulation (Tercero et al. 2018). According to (IMA Europe 2016), eliminating boron from fibreglass production is not possible without affecting the glass fibre properties and increasing production costs.

Furthermore, no practical substitutes are available for heat-resistant glass, nor for frits and ceramics that have to resist thermal shocks (Tercero et al. 2018). For those frits and ceramics that are to be used in tiles and floors, substitution is theoretically possible (Tercero et al. 2018) but no information is available on technically or economically viable alternative applications. According to (IMA Europe 2016), there are no substitutes in ceramic, or enamel glazes as the benefits provided by B_2O_3 in glaze production cannot be replaced by other oxides.

Finally, no substitution is possible in fertilisers because of the unique biological function of boron (Tercero et al. 2018).

In the criticality assessment, no substitution is considered available for the use of borates in the applications of 'Glass', 'Frits and ceramics' and 'Fertilisers'. The rest of the applications were not assessed due to less than 10 % share in total end uses. However, substitutes exist for wood preservatives (Tercero et al. 2018), soaps (sodium and potassium salts of fatty acids), detergents (sodium percarbonate which requires a lower temperature to undergo hydrolysis) and bleaches (chlorine) (USGS 2019a)(Graedel et al. 2015b). Finally, boron replacement in metal applications seems impractical due to the numerous uses (Tercero et al. 2018a).

On a scale of 0 to 100[43], the substitution potential of boron has been assessed as 41 by (Graedel et al. 2015).

6.3.4 EU supply chain

The boron flows through the EU economy in 2012 are demonstrated in Figure 81.

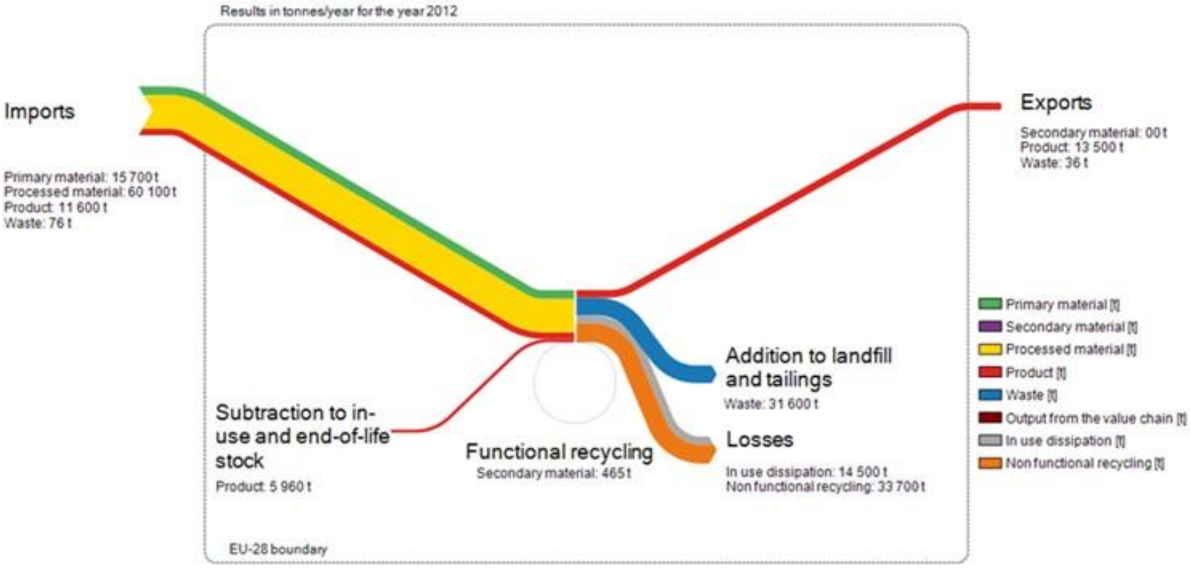

Figure 81: Simplified MSA of boron flows in the EU in 2012 (BIO Intelligence Service 2015).

The EU does not extract borates (WMD 2019) and has no known reserves (BIO Intelligence Service 2015a). Therefore, the EU is entirely reliant on imports of primary products (import reliance of 100%). Likewise, there are no manufacturing/processing plants to refine borates in the EU (IMA-Europe, 2016) (SCRREEN workshops 2019). However, it has to be mentioned that boric acid is produced in Italy from geothermal springs. Although it was the sole source of natural boric acid in the mid-19th century, the current contribution to the EU borates supply is minimal (RPA 2008) (Helvaci 2005).

[43] On this scale, zero indicates that exemplary substitutes exist for all major uses and 100 indicates that no substitute with even adequate performance exists for any of the major uses

The leading supplier of the EU for both natural and refined borates is Turkey, with a share of 98% and 60% of the EU sourcing, respectively. The US is a significant supplier of refined borates with a share of 35% of EU supply (Figure 82).

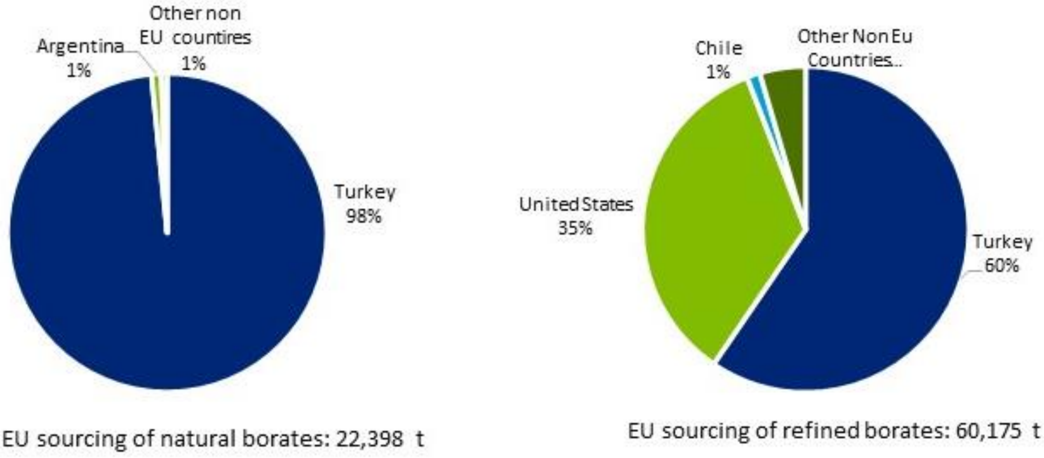

Figure 82: EU sourcing of borates. Average 2012-2016 (Eurostat Comext 2019).

6.3.5 Supply from primary materials

6.3.5.1 Geology, resources and reserves of borates

Geological occurrence: Borates are naturally occurring minerals containing boron (B). Boron does not occur naturally as a native element but is found in combination with oxygen and other elements in salts, commonly called "borates". Boron is a relatively rare element in nature, and the average content in the Earth's crust is reported between 10 (Helvacı 2017) and 17 ppm (Rudnick and Gao 2014). There are over 250 borate minerals occurring naturally, the most common being sodium, calcium, or magnesium salts (Helvacı 2017). Four of these account for 90% of the minerals used by the industry: the sodium borates tincal and kernite, the calcium borate colemanite, and the sodium-calcium borate ulexite (USGS 2018). Ore quality is typically measured as a function of its diboron trioxide (B_2O_3) equivalent content.

Deposits of borates are generally associated with arid climates and volcanically active areas; the largest are found in Turkey and the Mojave Desert in California of the United States. In the Puna region of the Andean belt of South America, which includes parts of Argentina, Peru, Bolivia, and Chile, commercial deposits of borates occur in brines (USGS 2018).

There is no information available on deposits of borates in the EU. In the geothermal springs of the Maremma region of Tuscany in Italy (Lardarello), natural steam carries boric acid recoverable as sassolite (Helvaci 2005).

Global resources and reserve[44]*:* The estimated known reserves of borates worldwide are about 1,093,000 kt in boron content (USGS 2019a). Approximately 75-80% of the

[44] There is no single source of comprehensive evaluations for resources and reserves that apply the same criteria to deposits of borates 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 which is also consistent with the United Nations Framework Classification (UNFC) system. However, reserve and resource data are changing

global boron reserves are located in Turkey, which are the world's highest-grade deposits of colemanite, ulexite and tincal with grades ranging from 25 to 30% of B_2O_3 (boric oxide) (Helvacı 2017).

Table 33: Global reserves of borates in 2018 (USGS 2019a)

Country	Reserves (kt of boron)	Percentage of the total (%)
Turkey	950,000	87%
Unites States	40,000	4%
Russia	40,000	4%
Chile	35,000	3%
China	24,000	2%
Peru	4,000	<1%
Argentina	NA	-
Bolivia	NA	-
Kazakhstan	NA	-
World total[45]	1,093,000	100%

EU resources and reserves*:* There are no known resources of borates in the EU. Table 34 presents available data on borate resources in Europe.

Table 34: Resources of borates in Europe

Country	Classification	Quantity (million t of ore)	Grade (% B_2O_3)	Reporting code	Reporting date	Source
Serbia	Indicated	5.6	30.8	NI 43-101	04/2015	(Minerals4EU 2019)
	Inferred	6.2	28.8			
	Indicated	52.4	19.2	JORC	12/2016	(Rio Tinto 2017)[46]
	Inferred	83.3	13.0			

6.3.5.2 Mining and refining of borates

Most of the world's commercial borate deposits are mined by open-pit methods, generally using truck and shovel or backhoe equipment (Carpenter and Kistler 2006).

Some applications permit the use of unrefined borates, such as colemanite and ulexite. However, natural borates often require refining as the ores are not of sufficient quality. High purity borax or boric acid are the main forms consumed by manufacturing industries for most applications.

Processing techniques depend on both the scale of the operation and the ore type (Helvaci 2005). The basic processing steps used to convert natural borates to refined products consist of ore crushing, leaching the ore in either hot water or acid, filtration to to remove insoluble impurities, cooling the concentrated borate solutions, dewatering to produce a moist cake of boric acid, washing and drying (Carpenter and Kistler 2006) . Several commercial forms of refined borates (or primary boron chemicals) exist:

continuously as exploration and mining proceed and are thus influenced by market conditions and should be followed continuously.

[45] The world total is given, even though reserves are not reported to the USGS in a consistent manner by all countries (USGS, 2019a)

[46] Jadar project

- high purity sodium borates (borax pentahydrate, borax decahydrate, anhydrous borax);
- high-purity boric acid and boron oxide (anhydrous boric acid).

6.3.5.3 World and EU production of natural borates

In the period 2012-2016, the average world mine production was about 918,968 t of boron minerals (in B content). In terms of volume, world production of boron minerals amounted to 4,594,840 t on average over the 2012-2016 period (WMD 2019). Turkey and the United States are the leading producers of natural borates accounting for more than two-thirds of natural borates output, followed by Argentina and Chile (Figure 83). There is no mining of borate minerals within the EU.

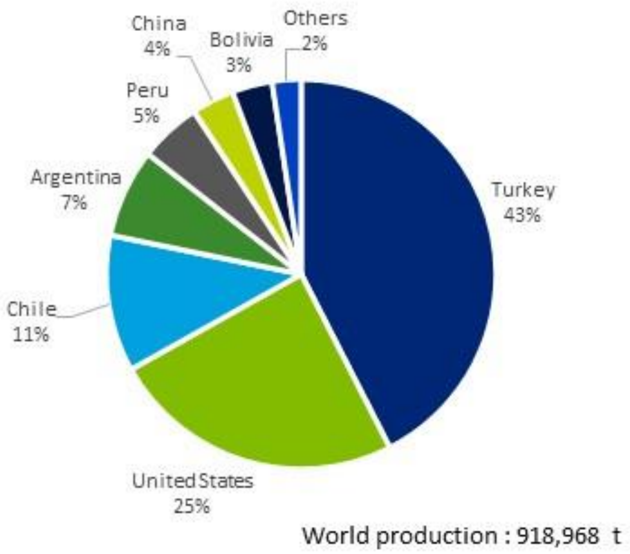

Figure 83: Global production of natural borates. Average for the years 2012-2016 (in B content) (WMD 2019)

6.3.5.4 World and EU production of refined borates

There is no publicly available data on the production of refined borates. Based on estimation from the global trade data as reported by UN Comtrade (2019), US is the dominant supplier of refined borates accounting for 67% of the total world exports. The average annual quantity of the processed borate products traded over 2012-2016 is around 163,500 t of borate content. The trade codes used for the indirect estimation of world production shares are:

- Oxides of boron, boric acids (HS6 281000, B content 17%). World exports 508,125 t by volume;
- Borates, disodium tetraborate (refined borax), anhydrous (HS6 284011, B content 21%). World exports 68,896 t by volume;
- Borates, disodium tetraborate (refined borax), other than anhydrous (HS6 284019, B content: 12%). World exports 701,756 t by volume;

Refined borates are not produced in the EU (IMA-Europe, 2016) (SCRREEN workshops 2019).

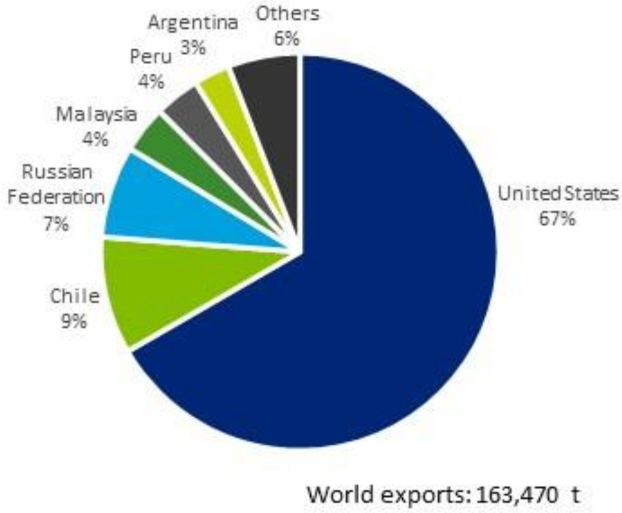

Figure 84: Estimated distribution of world production of processed borates. Average for the period 2012-2016 (in B content). (UN Comtrade 2019)

6.3.6 Supply from secondary materials/recycling

Because of the nature of end uses, boron/borates functional recycling is not possible as products are consumed with the use (e.g. fertilisers, chemicals and detergents), or because non-functional recycling only occurs. For instance, separation of borosilicate glass from the boron-free container and flat glass is not possible and, as a result, waste borosilicate glass will end up in the manufacture of normal glass, causing defects in the final product. Moreover, waste from ceramics is mostly used as a construction material (BIO Intelligence Service 2015). As an exception, the recycling of biogenic wastes (e.g. manure or other animal by-products, bio- and food wastes) can be considered as functional recycling because it may replace boron from industrial fertilisers(Mathieux et al. 2017). The EoL-RIR (End-of-Life Recycling Input Rate) for boron is less than 1% (SCRREEN workshops 2019).

Table 35: Material flows relevant to the EOL-RIR of borates[47] in 2012. Data from (BIO Intelligence Service 2015).

MSA Flow	Value (t)
B.1.1 Production of primary material as the main product in EU sent to processing in EU	0
B.1.2 Production of primary material as by-product in EU sent to processing in EU	0
C.1.3 Imports to EU of primary material	15,739
C.1.4 Imports to EU of secondary material	0
D.1.3 Imports to EU of processed material	60,050
E.1.6 Products at end of life in EU collected for treatment	65,778
F.1.1 Exports from EU of manufactured products at end-of-life	36
F.1.2 Imports to EU of manufactured products at end-of-life	75
G.1.1 Production of secondary material from post-consumer functional recycling in EU sent to processing in EU	0
G.1.2 Production of secondary material from post-consumer functional recycling in EU sent to manufacture in EU	464

47 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)

6.4 Other considerations

6.4.1 Environmental and health and safety issues

Certain boron compounds have been identified as Substances of Very High Concern (SVHC) under Regulation (EC) 2006/1997 (REACH) and have been included in the candidate list for authorisation due to their classification as toxic for reproduction, cat. 1B (meeting the criteria of Art. 57 (c) of the REACH Regulation (ECHA 2019a).
The Candidate List of Substances of Very High Concern (SVHC), as published on ECHA's website, contains the following borates:

- Boric acid, anhydrous disodium tetraborate and tetraboron disodium heptaoxide-hydrate were included in 2010;
- Diboron trioxide and Lead bis (tetrafluoroborate) were included in the same list in 2012;
- Sodium perborate; perboric acid, sodium salt and Sodium peroxometaborate included in 2014;
- Disodium octaborate added in the list in 2018.

Several boric acids and borates cannot be placed on the market or used as a substance, as constituent of another substance or in mixtures for supply to the general public when the individual concentration in the substance or mixture is equal to or greater than 0,3%. The packaging must be marked visibly, legible and indelibly "Restricted to professional users"[48].

Companies may have immediate legal obligations following the inclusion of a substance in the Candidate List as explained on ECHA's website, in particular, specific communication requirements (ECHA 2019b). Inclusion on Annex XIV (the Authorization list) is not automatically triggered by the inclusion on the Candidate List. Currently (July 2019), ECHA has recommended to the European Commission from the "Candidate List" as priority substances for inclusion in Annex XIV of REACH (the "Authorisation List") the following borates (ECHA, 2019c):

- Disodium tetraborate, anhydrous (from July 2015);
- Sodium perborate; perboric acid, sodium salt (from November 2016);
- Sodium peroxometaborate (from November 2016).

As regards the potential impact of REACH on defence applications, the European Defence Agency reports that boric acid has very critical uses in surface treatment, i.e. in electrolytic deposition of metals, acidity regulators, cleaning, anodising. It is also useful for metalworking fluids and brazing fluxes as well as in submarine propulsion and for the control of nuclear reactions. Another relevant issue is related to boron oxide that is an essential reagent in the manufacturing process of gallium arsenide (GaAs), which is a semiconductor compound with some electronic properties superior to those of silicon (EDA 2018).

EU OSH requirements exist to protect workers' health and safety, employers need to identify which hazardous substances they use at the workplace, carry out a risk assessment and introduce appropriate, proportionate and effective risk management measures to eliminate or control exposure, to consult with the workers who should receive training and, as appropriate, health surveillance[49].

According to the Committee for Risk Assessment (RAC) opinion[50] adopted on 20/09/2019, boric acid and sodium borates are classified as follows:

[48] Annex XVII entry 30 and Appendix 6 of Regulation (EC) 1907/2006 (REACH).

[49] https://ec.europa.eu/social/main.jsp?catId=148

[50] https://www.echa.europa.eu/documents/10162/23665416/clh_opinion_Boric+acid+and+sodium+borates_13456_en.pdf/584263da-199c-f86f-9b73-422a4f22f1c3

- boric acid: Repr. 1B
- diboron trioxide: Repr. 1B (GCL of 0.3%)
- tetraboron disodium heptaoxide, hydrate: Repr. 1B (GCL of 0.3%)
- disodium tetraborate decahydrate: Repr. 1B (GCL of 0,3%)
- disodium tetraborate pentahydrate: Repr. 1B (GCL of 0.3%)

6.4.2 Contribution to low-carbon technologies

A role for borates in the implementation of the European Commission's long-term strategy for a modern, competitive, prosperous and climate-neutral economy by 2050 [51], is identified in wind turbines, as boron is a key ingredient in the most powerful magnet material, namely neodymium-iron-boron (NdFeB). This magnet is used to manufacture permanent magnets for synchronous generators (PMSG), which are used in all major wind turbine configurations (Blagoeva et al. 2016).

Moreover, insulation through the use of glass wool, coupled with high-performance glazing in buildings, has the potential to enable more than 80% energy savings from buildings (Wyns, Khandekar, and Robson 2018).

A fast growing application of borosilicate glass is in solar thermal heating; these are used in both domestic and industrial technologies. In the former, borosilicate glass tubes contain a solar collector in order to capture the energy. In the latter, these tubes are used to carry heat transfer fluids.

Finally, boron is identified as a material that can be used for storage of hydrogen in fuel cell and hydrogen-related technologies (Blagoeva et al. 2019).

6.4.3 Socio-economic issues

The governance level in Turkey, the dominant supplier of natural borates for the EU, is low especially in the "political stability and absence of violence/terrorism" area, with a sharp deterioration of this indicator in the decade 2006-2016 (World Bank 2018).

6.5 Comparison with previous EU assessments

The assessment has been conducted using the same methodology as for the 2017 list. In the current assessment, the supply risk has been analysed at the mine and, additionally to the 2017 assessment, at the processing stage. The results of this and earlier assessments are shown in Table 36.

Table 36: Economic importance and supply risk results for borates 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
Borates	5.0	0.6		5.7	1.0		3.1	3.0		3.5	3.2

The results of the previous assessments are not directly comparable due to the introduction of a revised methodology in the 2017 assessment. For example, the economic importance appears reduced in the 2017 assessment as the value-added considered in the 2017 criticality assessment corresponds to a 2-digit NACE sector rather than a 'megasector' (which was used in the previous assessments).

51 https://ec.europa.eu/clima/policies/strategies/2050_en

In the current assessment, the higher supply risk is identified for the mine stage (SR=3.2) than the processing stage (SR=1.8) reflecting a higher EU supply concentration at the mining stage in comparison to the refining stage. The overall supply risk for borates is considered for the stage with the highest value, i.e. SR=3.2. The supply risk has increased compared to 2017 exercise due to the growing supply concentration, both global and for the EU.

The Economic Importance indicator (EI) is higher in the current assessment compared to the 2017 exercise. This is mainly due to the results scaling step[52], as the value-added of the largest manufacturing sector in the current assessment is lower as it corresponds to 27 Member States (i.e. excluding UK), whereas in the 2017 assessment it was related to 28 Member States. The slightly different allocation of shares to each end use sector in comparison to the 2017 assessment, and the correspondence of the application "Wood preservatives" to the C20 2-digit NACE sector "C20 - Manufacture of chemicals and chemical products" instead of ''C16 - Manufacture of wood and of products of wood and cork, except furniture'' as in the 2017 assessment, had a negligible effect in the increase of EI.

6.6 Data sources

For the stage of extraction (natural borates), data developed by the Austrian Ministry for Sustainability and Tourism and the International Organising Committee for the World Mining Congress were used (World Mining Data). Data for refined borate production are not available. Thus, the global production of refined borates was approximated/modelled from world exports of refined borate products (UN Comtrade) based on common hypotheses and calculation of boron amount by stoichiometric principles. Eurostat (Comext) was the source of data for EU trade flows of natural borates. For refined borates, trade data were sourced from the World Integrated Trade Solution (WITS) database developed by the World Bank, in collaboration with the United Nations Conference on Trade and Development (UNCTAD). For the analysis of EU borates consumption per application, data provided by IMA Europe in the context of the 2015 MSA study and the 2017 criticality assessment were used (IMA Europe 2016).

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